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National Toxicology Program
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NTP Technical Report on the Toxicology and Carcinogenesis Studies in B6C3F1/N Mice Exposed to Whole-body Radio Frequency Radiation at a Frequency (1,900 MHz) and Modulations (GSM and CDMA) Used by Cell Phones

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Foreword

The National Toxicology Program (NTP) is an interagency program within the Public Health Service (PHS) of the Department of Health and Human Services (HHS) and is headquartered at the National Institute of Environmental Health Sciences of the National Institutes of Health (NIEHS/NIH). Three agencies contribute resources to the program: NIEHS/NIH, the National Institute for Occupational Safety and Health of the Centers for Disease Control and Prevention (NIOSH/CDC), and the National Center for Toxicological Research of the Food and Drug Administration (NCTR/FDA). Established in 1978, NTP is charged with coordinating toxicological testing activities, strengthening the science base in toxicology, developing and validating improved testing methods, and providing information about potentially toxic substances to health regulatory and research agencies, scientific and medical communities, and the public.

The Technical Report series began in 1976 with carcinogenesis studies conducted by the National Cancer Institute. In 1981, this bioassay program was transferred to NTP. The studies described in the Technical Report series are designed and conducted to characterize and evaluate the toxicologic potential, including carcinogenic activity, of selected substances in laboratory animals (usually two species, rats and mice). Substances selected for NTP toxicity and carcinogenicity studies are chosen primarily on the basis of human exposure, level of production, and chemical structure. The interpretive conclusions presented in NTP Technical Reports are based only on the results of these NTP studies. Extrapolation of these results to other species, including characterization of hazards and risks to humans, requires analyses beyond the intent of these reports. Selection *per se* is not an indicator of a substance's carcinogenic potential.

NTP conducts its studies in compliance with its laboratory health and safety guidelines and FDA Good Laboratory Practice Regulations and must meet or exceed all applicable federal, state, and local health and safety regulations. Animal care and use are in accordance with the Public Health Service Policy on Humane Care and Use of Animals. Studies are subjected to retrospective quality assurance audits before being presented for public review.

The NTP Technical Reports are available free of charge on the NTP website and cataloged in PubMed, a free resource developed and maintained by the National Library of Medicine (part of the National Institutes of Health). Data for these studies are included in NTP's Chemical Effects in Biological Systems database.

For questions about the reports and studies, please email NTP or call 984-287-3211.

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This report has been reformatted to meet new NTP publishing requirements;
its content has not changed.

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Explanation of Levels of Evidence of Carcinogenic Activity

The National Toxicology Program describes the results of individual experiments on a test agent and notes the strength of the evidence for conclusions regarding each study. Negative results, in which the study animals do not have a greater incidence of neoplasia than control animals, do not necessarily mean that a test agent is not a carcinogen, inasmuch as the experiments are conducted under a limited set of conditions. Positive results demonstrate that a test agent is carcinogenic for laboratory animals under the conditions of the study and indicate that exposure to the test agent has the potential for hazard to humans. Other organizations, such as the International Agency for Research on Cancer, assign a strength of evidence for conclusions based on an examination of all available evidence, including animal studies such as those conducted by NTP, epidemiologic studies, and estimates of exposure. Thus, the actual determination of risk to humans from test agents found to be carcinogenic in laboratory animals requires a wider analysis that extends beyond the purview of these studies.

Five categories of evidence of carcinogenic activity are used in the Technical Report series to summarize the strength of evidence observed in each experiment: two categories for positive results **(clear evidence and some evidence)**; one category for uncertain findings **(equivocal evidence)**; one category for no observable effects **(no evidence)**; and one category for experiments that cannot be evaluated because of major flaws **(inadequate study)**. These categories of interpretative conclusions were first adopted in June 1983 and then revised on March 1986 for use in the Technical Report series to incorporate more specifically the concept of actual weight of evidence of carcinogenic activity. For each separate experiment (male rats, female rats, male mice, female mice), one of the following five categories is selected to describe the findings. These categories refer to the strength of the experimental evidence and not to potency or mechanism.

- **Clear evidence** of carcinogenic activity is demonstrated by studies that are interpreted as showing a dose-related (i) increase of malignant neoplasms, (ii) increase of a combination of malignant and benign neoplasms, or (iii) marked increase of benign neoplasms if there is an indication from this or other studies of the ability of such tumors to progress to malignancy.
- **Some evidence** of carcinogenic activity is demonstrated by studies that are interpreted as showing a test agent-related increased incidence of neoplasms (malignant, benign, or combined) in which the strength of the response is less than that required for clear evidence.
- **Equivocal evidence** of carcinogenic activity is demonstrated by studies that are interpreted as showing a marginal increase of neoplasms that may be test agent related.
- **No evidence** of carcinogenic activity is demonstrated by studies that are interpreted as showing no test agent-related increases in malignant or benign neoplasms
- **Inadequate study** of carcinogenic activity is demonstrated by studies that, because of major qualitative or quantitative limitations, cannot be interpreted as valid for showing either the presence or absence of carcinogenic activity.

For studies showing multiple test agent-related neoplastic effects that if considered individually would be assigned to different levels of evidence categories, the following convention has been

adopted to convey completely the study results. In a study with clear evidence of carcinogenic activity at some tissue sites, other responses that alone might be deemed some evidence are indicated as “were also related” to test agent exposure. In studies with clear or some evidence of carcinogenic activity, other responses that alone might be termed equivocal evidence are indicated as “may have been” related to test agent exposure.

When a conclusion statement for a particular experiment is selected, consideration must be given to key factors that would extend the actual boundary of an individual category of evidence. Such consideration should allow for incorporation of scientific experience and current understanding of long-term carcinogenesis studies in laboratory animals, especially for those evaluations that may be on the borderline between two adjacent levels. These considerations should include:

- adequacy of the experimental design and conduct;
- occurrence of common versus uncommon neoplasia;
- progression (or lack thereof) from benign to malignant neoplasia as well as from preneoplastic to neoplastic lesions;
- some benign neoplasms have the capacity to regress but others (of the same morphologic type) progress. At present, it is impossible to identify the difference. Therefore, where progression is known to be a possibility, the most prudent course is to assume that benign neoplasms of those types have the potential to become malignant;
- combining benign and malignant tumor incidence known or thought to represent stages of progression in the same organ or tissue;
- latency in tumor induction;
- multiplicity in site-specific neoplasia;
- metastases;
- supporting information from proliferative lesions (hyperplasia) in the same site of neoplasia or other experiments (same lesion in another sex or species);
- presence or absence of dose relationships;
- statistical significance of the observed tumor increase;
- concurrent control tumor incidence as well as the historical control rate and variability for a specific neoplasm;
- survival-adjusted analyses and false positive or false negative concerns;
- structure-activity correlations; and
- in some cases, genetic toxicology.

Peer Review

The members of the Peer Review Panel who evaluated the draft *NTP Technical Report on the Toxicology and Carcinogenesis Studies in B6C3F1/N Mice Exposed to Whole-body Radio Frequency Radiation at a Frequency (1,900 MHz) and Modulations (GSM and CDMA) Used by Cell Phones* on March 26–28, 2018, are listed below. Panel members served as independent scientists, not as representatives of any institution, company, or governmental agency. The panel was divided into two groups. Panel 1 provided consultation on the reverberation chamber technology and Panel 2 provided recommendations on the study findings and NTP's draft conclusions. In this capacity, reviewers were charged to:

Panel 1:

- Assess the reverberation chamber technology for evaluating the effects of cell phone radiofrequency radiation exposure in mice.

Panel 2:

- Review and evaluate the scientific and technical elements of the study and its presentation.
- Determine whether the study's experimental design, conduct, and findings support NTP's conclusions regarding the carcinogenic activity and toxicity of the test agent.

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Abstract

The predominant source of human exposure to radio frequency radiation (RFR) occurs through usage of cellular phone handsets. The Food and Drug Administration nominated cell phone RFR emission for toxicology and carcinogenicity testing in 1999. At that time, animal experiments were deemed crucial because meaningful human exposure health data from epidemiological studies were not available. Male and female B6C3F1/N mice were exposed to time-averaged whole-body specific absorption rates of 0 (sham control), 5, 10, or 15 W/kg Global System for Mobile Communications (GSM)- or Code Division Multiple Access (CDMA)-modulated cell phone RFR at 1,900 MHz for 28 days or 0, 2.5, 5, or 10 W/kg GSM- or CDMA-modulated cell phone RFR for up to 2 years. Genetic toxicology studies were conducted in mouse peripheral blood erythrocytes and leukocytes, brain cells, and liver cells.

GSM

Twenty-eight-day Study

Groups of 10 male and 10 female mice were housed in specially designed reverberation chambers and received whole-body exposures to GSM-modulated cell phone RFR at power levels of 0 (sham control), 5, 10, or 15 W/kg, for up to 18 hours and 20 minutes per day, 5 or 7 (last week of study) days per week for at least 28 days with continuous cycling of 10 minutes on and 10 minutes off during the exposure periods. The sham control animals were housed in reverberation chambers identical to those used for the exposed groups, but were not exposed to cell phone RFR; a shared group of unexposed mice of each sex served as sham controls for both cell phone RFR modulations. All mice survived to the end of the study. Mean body weights of exposed groups of males and females were similar to the sham controls. There were no exposure-related clinical signs, differences in organ weights, or histopathologic findings. Differences in body temperatures between the exposed groups and the sham control group were not considered to be related to cell phone RFR exposure.

Two-year Study

Groups of 105 male and 105 female mice were housed in reverberation chambers and received whole-body exposures to GSM-modulated cell phone RFR at power levels of 0 (sham control), 2.5, 5, or 10 W/kg, 9 hours and 10 minutes per day, 7 days per week for 106 (males) or 108 (females) weeks with continuous cycling of 10 minutes on and 10 minutes off during a period of 18 hours and 20 minutes each day. The sham control animals were housed in reverberation chambers identical to those used for the exposed groups, but were not exposed to RFR; shared groups of unexposed mice of each sex served as sham controls for both RFR modulations. Fifteen mice per group were randomly selected from the core group after 10 weeks of study; 10 of those 15 mice per group were used for interim evaluation at 14 weeks, and five mice per group were used for genetic toxicity testing at 14 weeks. The remaining 90 animals per group were exposed up to 2 years.

At the 14-week interim evaluation in the 2-year study, mean body weights of exposed groups of males and females were similar to those of the sham controls. There were no changes to the hematology variables attributable to GSM RFR exposure. Differences in organ weights were not associated with histopathologic findings and were not considered related to exposure. In males, there were no exposure-related effects on reproductive organ weights, testis spermatid concentrations, caudal epididymal sperm concentrations, or sperm motility. In females, there

were no exposure-related effects on estrous cycle length, number of cycling females, or relative amount of time spent in the estrous stages.

In the 2-year study, percent survival was significantly higher for the 5 W/kg males than the sham control group. Survival of the other exposed groups of males and females was generally similar to that of the sham controls. Mean body weights of exposed groups of males and females were similar to those of the sham controls throughout the study.

The combined incidences of fibrosarcoma, sarcoma, or malignant fibrous histiocytoma of the skin were increased in 5 and 10 W/kg males, although not significantly or in a SAR-related manner; however, the incidences exceeded the overall historical control ranges for malignant fibrous histiocytoma. In the lung, there was a significant positive trend in the incidences of alveolar/bronchiolar adenoma or carcinoma (combined) in males. Compared to the sham controls, all exposed groups of females had increased incidences of malignant lymphoma and the incidences in the 2.5 and 5 W/kg groups were significantly increased. The sham control group had a low incidence of malignant lymphoma compared to the range seen in historical controls.

There were no nonneoplastic lesions that were considered related to exposure to GSM-modulated cell phone RFR.

CDMA

Twenty-eight-day Study

Groups of 10 male and 10 female mice were housed in reverberation chambers and received whole-body exposures to CDMA-modulated cell phone RFR at power levels of 0 (sham control), 5, 10, or 15 W/kg, for up to 18 hours and 20 minutes per day, 5 or 7 (last week of study) days per week for at least 28 days with continuous cycling of 10 minutes on and 10 minutes off during the exposure periods. The sham control animals were housed in reverberation chambers identical to those used for the exposed groups, but were not exposed to RFR; a shared group of unexposed mice of each sex served as sham controls for both RFR modulations. All mice survived to the end of the study. Mean body weights of exposed groups of males and females were similar to the sham controls. There were no exposure-related clinical signs, differences in organ weights, or histopathologic findings. Differences in body temperatures between the exposed groups and the sham control group were not considered to be related to RFR exposure.

Two-year Study

Groups of 105 male and 105 female mice were housed in reverberation chambers and received whole-body exposures to CDMA-modulated cell phone RFR at power levels of 0 (sham control), 2.5, 5, or 10 W/kg, 9 hours and 10 minutes per day, 7 days per week for 106 (males) or 108 (females) weeks with continuous cycling of 10 minutes on and 10 minutes off during a period of 18 hours and 20 minutes each day. The sham control animals were housed in reverberation chambers identical to those used for the exposed groups, but were not exposed to RFR; shared groups of unexposed mice of each sex served as sham controls for both RFR modulations. Fifteen mice per group were randomly selected from the core group after 10 weeks of study; 10 of those 15 mice per group were used for interim evaluation at 14 weeks, and five mice per group were used for genetic toxicity testing at 14 weeks. The remaining 90 animals per group were exposed up to 2 years.

At the 14-week interim evaluation of the 2-year study, mean body weights of exposed groups of males and females were similar to those of the sham controls. There were no changes to the hematology variables attributable to CDMA-modulated RFR exposure. Differences in organ

weights in male mice were not associated with histopathologic findings and were not considered related to exposure; there were no significant changes in organ weights in females. In males, there were no exposure-related effects on reproductive organ weights, testis spermatid concentrations, caudal epididymal sperm concentrations, or sperm motility. In females, there were no exposure-related effects on estrous cyclicity. Compared to the sham controls, there were statistically significant differences for extended estrous in the 2.5 W/kg group and extended diestrus in the 5 W/kg group; however, these changes were considered sporadic due to the lack of an exposure-related response. In the kidney of 10 W/kg females, there was a significantly increased incidence of minimal to mild interstitial lymphocytic cellular infiltration.

Percent survival was significantly higher in 2.5 W/kg males compared to that in the sham controls in the 2-year study. Survival of males and females in all other exposed groups was generally similar to that of the sham controls. Mean body weights of exposed groups of males and females were similar to those of the sham controls throughout the study.

There was a significantly increased incidence of hepatoblastoma in 5 W/kg males. Compared to the sham controls, the incidences of malignant lymphoma were increased in all exposed groups of females, and the increase was significant in the 2.5 W/kg group. As noted for the GSM study, the shared sham control group had a low incidence of malignant lymphoma compared to the range observed in historical controls.

There were no nonneoplastic lesions that were considered related to exposure to CDMA-modulated cell phone RFR.

Genetic Toxicology

Comet Assay

As part of the 14-week interim evaluation, samples of frontal cortex, hippocampus, cerebellum, liver, and blood leukocytes were evaluated for DNA damage using the comet assay (two sexes, two RFR modulations, and five tissues per animal). Samples of peripheral blood from these same animals were also evaluated for chromosome damage in the micronucleus assay. Results in the comet assay are based on the 100-cell scoring approach that was standard at the time of the study; data obtained using a second 150-cell scoring approach, recommended in a recently adopted international guideline for the in vivo comet assay, are noted for the few instances where results differed between the two methods. Significant increases in DNA damage were observed in cells of the frontal cortex of male mice exposed to both modulations, GSM and CDMA. No other tissues showed evidence of an exposure-related effect in male mice. In female mice exposed to the CDMA modulation, significant increases in DNA damage were seen in blood leukocytes at all three exposure levels using both scoring approaches. No statistically significant increases in percent comet tail DNA were observed in any of the samples from female mice exposed to the GSM modulation with the 100-cell scoring method. Scoring 150 cells resulted in a significant response in liver of female mice exposed to CDMA; a similar pattern of response was seen with the 100-cell scoring method, but none of the increases were significant.

Micronucleus Assay

No significant increases in micronucleated red blood cells or changes in the percentage of immature erythrocytes among total erythrocytes were observed in the peripheral blood of mice of either sex exposed to either modulation of RFR.

Conclusions

Under the conditions of these 2-year studies, there was *equivocal evidence of carcinogenic activity* (see Explanation of Levels of Evidence of Carcinogenic Activity; see a summary of the Peer Review Panel comments and the public discussion on this Technical Report appears in Appendix L) of GSM-modulated cell phone RFR at 1,900 MHz in male B6C3F1/N mice based on the combined incidences of fibrosarcoma, sarcoma, or malignant fibrous histiocytoma in the skin and the incidences of alveolar/bronchiolar adenoma or carcinoma (combined) in the lung. There was *equivocal evidence of carcinogenic activity* of GSM-modulated cell phone RFR at 1,900 MHz in female B6C3F1/N mice based on the incidences of malignant lymphoma (all organs). There was *equivocal evidence of carcinogenic activity* of CDMA-modulated cell phone RFR at 1,900 MHz in male B6C3F1/N mice based on the incidences of hepatoblastoma of the liver. There was *equivocal evidence of carcinogenic activity* of CDMA-modulated cell phone RFR at 1,900 MHz in female B6C3F1/N mice based on the incidences of malignant lymphoma (all organs).

Exposure to GSM- or CDMA-modulated cell phone RFR at 1,900 MHz did not increase the incidence of any nonneoplastic lesions in male or female B6C3F1/N mice.

Synonyms: Cell phone radio frequency radiation; mobile phone radio frequency radiation

Summary of the Two-year Carcinogenesis and Genetic Toxicology Studies of GSM- and CDMA-modulated Cell Phone RFR Exposure in Mice

	GSM-modulated Cell Phone RFR Male Mice	GSM-modulated Cell Phone RFR Female Mice	CDMA-modulated Cell Phone RFR Male Mice	CDMA-modulated Cell Phone RFR Female Mice
Whole-body GSM- or CDMA-modulated cell phone RFR exposure	0, 2.5, 5, or 10 W/kg	0, 2.5, 5, or 10 W/kg	0, 2.5, 5, or 10 W/kg	0, 2.5, 5, or 10 W/kg
Survival rates	66/90, 63/90, 80/90, 72/90	67/90, 74/90, 70/90, 73/90	66/90, 83/91, 71/90, 71/90	67/90, 75/89, 70/90, 72/90
Body weights	Exposed groups similar to the sham control group	Exposed groups similar to the sham control group	Exposed groups similar to the sham control group	Exposed groups similar to the sham control group
Nonneoplastic effects	None	None	None	None
Neoplastic effects	None	None	None	None
Equivocal findings	Skin: fibrosarcoma, sarcoma, or malignant fibrous histiocytoma (1/90, 1/89, 5/90, 4/90) Lung: alveolar/bronchiolar adenoma or carcinoma (23/90, 24/89, 32/90, 34/90)	All organs: malignant lymphoma (2/90, 13/90, 9/90, 6/90)	Liver: hepatoblastoma (6/90, 6/89, 16/90, 7/90)	All organs: malignant lymphoma (2/90, 9/89, 6/90, 7/90)
Level of evidence of carcinogenic activity	Equivocal evidence	Equivocal evidence	Equivocal evidence	Equivocal evidence
Genetic toxicology				
DNA damage:				
GSM-modulated		Positive in frontal cortex (males); negative in frontal cortex (females); negative in hippocampus, cerebellum, liver, and leukocytes (males and females)		
CDMA-modulated		Positive in frontal cortex (males) and leukocytes (females); negative in hippocampus, cerebellum, and liver (males and females); negative in leukocytes (males) and frontal cortex (females)		
Micronucleated erythrocytes in peripheral blood in vivo:				
GSM-modulated		Negative in males and females		
CDMA-modulated		Negative in males and females		

Introduction

Overview

All consumer cell phone devices function through the transmission of radio waves on a cellular network. The cellular network itself is composed of a collection of individual “cells” that include a fixed-location transceiver (a device that transmits and receives radio signals), also referred to as a cell tower. The collection of adjacent smaller “cells” in the cellular network enables cell phones and towers to use low-power transmitters, thereby allowing for the same frequencies to be reused in non-adjacent cells without interference. Together the individual “cells” comprise the cellular network that provides coverage over a large geographical area. In the United States two major nationwide cellular technologies in use are CDMA (Code Division Multiple Access) and GSM (Global System for Mobile Communications). While technologies are rapidly evolving to meet consumers’ increased demand for better coverage, increased call quality, faster data transfer rates, and increased accessibility, in the context of this report, the terms CDMA and GSM group together multiple, sometimes successive, technologies that are implemented by the service providers that maintain the service networks. In the United States, Sprint® and Verizon® networks use CDMA; AT&T® and T-Mobile® use GSM.

For both the GSM and CDMA technologies, transmissions occur at specific radio frequencies, which are allocated and regulated by the Federal Communications Commission (FCC). While the transmission of radio signals (radiofrequency radiation) can occur at the same frequencies for both technologies, they differ in the method by which information is incorporated and transmitted within frequency bands. In telecommunications, these are referred to as signal modulations. Because this process differs for CDMA and GSM, cell phones are not interchangeable between the two network technologies and will only function on one or the other.

The constantly evolving cellular technologies are commonly referred to by their successive generations (G). The first generation (1G) devices were analogue phones, as opposed to the digital phones of today. Digital voice systems of the second generation (2G) replaced the analogue system of 1G. At the time that these studies were being designed, 2G technology was the primary technology in use and 3G technologies were emerging. Therefore, the current studies were conducted using modulated signals that replicated the 2G and 3G technology in use at the time. Over the course of the studies, however, more advanced 4G technologies were developed. Currently, all of these technologies (2G, 3G, and 4G) are still actively in use for mobile communication applications. 2G and 3G are still the basis for voice calling applications, while 3G and 4G technologies were primarily developed to offer faster access to the internet. Some of the 3G technology is based on 2G technology. While 2G technology is being phased out in the United States, this technology will remain in use in other places throughout the world. More advanced and efficient technologies that are currently in development and not yet deployed, termed 5G, will utilize higher frequencies than existing technologies.

Radio Frequency Radiation (RFR) Measurement and Applications

RFR is a form of nonionizing electromagnetic energy that consists of propagating electromagnetic waves of oscillating electric (E-) and magnetic (H-) fields that move together at

the speed of light. RF waves are characterized by their wavelength (the distance covered by one complete cycle of the electromagnetic wave) and their frequency (the number of electromagnetic waves passing a given point in 1 second). The frequency of an RF signal is expressed in terms of Hertz (Hz), where one Hz is equivalent to one cycle per second. RF radiation refers to the region of the electromagnetic spectrum from 3 kilohertz (3 kHz) to 300 gigahertz (300 GHz) (Figure 1). As opposed to ionizing radiation, which contains enough energy when passing through matter to break chemical bonds or remove an electron from an atom or molecule to produce charged ions, nonionizing radiation has at most sufficient energy for excitation of an electron to a higher energy state.

The intensity of an RF field can be expressed by its electric and magnetic components and is measured in volts per meter (V/m) for electric fields and amperes per meter (A/m) for magnetic fields. Another measure of RFR is the power density, which is defined as the power per unit area and is expressed in watts per square meter (W/m^2). The quantity used to describe the amount of RFR energy absorbed by the body is referred to as the specific absorption rate (SAR), which is expressed in watts per kilogram (W/kg). SAR is a function of the geometry and the dielectric loss properties of biological tissues absorbing the energy (which results from the interaction of electromagnetic radiation with constituents at the cellular and molecular level), the square of the strength of the induced E-field, and the mass density of the exposed tissue. The SAR value is derived by averaging the absorbed energy over a specific volume (typically 1 gram, 10 grams, or the whole body for regulatory purposes).

Different applications utilize different frequency bands within the RF portion of the electromagnetic spectrum. RF frequencies for radio and television are in the 145 kHz to 850 MHz range. Wireless communications and networking typically utilize frequencies between 800 MHz and 6 GHz. Cell phone networks that are currently in use (2G, 3G, and 4G) utilize frequencies in the range of 600 MHz to 5.7 GHz. In the United States, wireless telecommunications networks and devices operate in bands at frequencies of nominally 800 MHz, 850 MHz, or 1,900 MHz for 2G; 850 MHz, 1,700 MHz, 1,900 MHz, or 2,100 MHz for 3G; and 600 MHz, 700 MHz, 800 MHz, 850 MHz, 1,700 MHz, 1,900 MHz, 2,100 MHz, 2,300 MHz, 2,500 MHz, 5,200 MHz, or 5,700 MHz for 4G. The next generation, i.e., the 5th generation of wireless communications, will also utilize the RFR spectrum above 6 GHz. Other terms are also used in the literature for part of the RFR spectrum, e.g., microwaves for frequencies above 1 GHz, and millimeter waves for frequencies above 30 GHz.

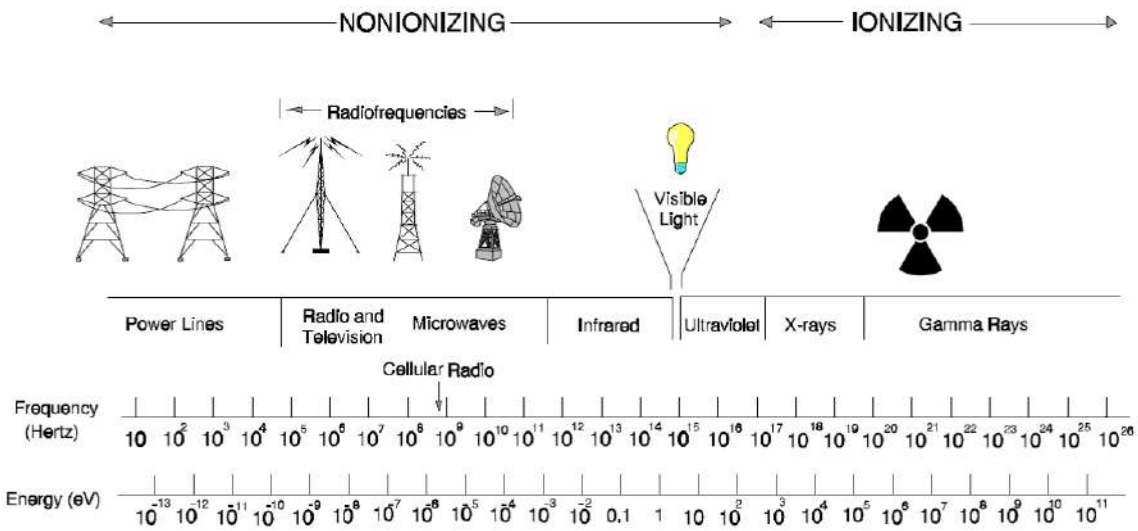

Figure 1. Electromagnetic Spectrum[1]

Cell Phones and RFR

Cell phones and other commonly used wireless communication devices are essentially two-way radios that contain both a receiver and a transmitter. When a user makes a call, voice sound is converted into digital information. The information is imposed on to RFR and transmitted to the nearest base station, commonly referred to as a cell tower, that receives and transmits RF signals and forms a bridge to the rest of the communications infrastructure. The base station receives and transmits radio signals in its area or "cell." As the user moves around, the radio signal can be relayed within the communications network from one "cell" of coverage to another, maintaining call connection. The call is routed through the communications network either through a landline phone or another wireless phone again using radio signals. To conserve energy and minimize interference, mobile phones automatically regulate the RFR signal strength, and hence the emitted field, to the lowest power level possible for a connection to be made. However, in a poor transmission environment (caused by, e.g., a distant base station, presence of obstacles between the base station and the mobile phone, or interference from adjacent cells), there is a higher output power and emission from the mobile phone in order to make a connection. Therefore, the better the connection, the lower the power output of the wireless device.

Cell Phone RFR Signal Modulation

In wireless telecommunications, modulation is the process of conveying digital or analog signals or information (the message) by varying one or more parameters of another signal (the carrier), typically at a much higher frequency. The modulated carrier contains complete information about the message signal and the original message can be recovered by suitable signal processing of the signal when received at a remote location (base station). One of the main goals of the modulation used in mass wireless communications systems is to transfer as much data as possible in the least amount of spectrum. Over the years, multiple modulation techniques have emerged to achieve and improve spectral efficiency, either when considering a single user in isolation or multiple users simultaneously using the same spectrum.

The first generation (1G) of wireless technology introduced in the 1980s, used analog frequency modulation for voice calls. This technology was replaced by second-generation (2G) networks that were digital, provided encryption, were significantly more efficient, and introduced data services [i.e., text messages, picture messages, and Multimedia Message Service (MMS)] in addition to voice calls. The 2G networks became commercially available in 1992 and used three common multiple access technologies for accommodating multiple simultaneous users:

- Frequency Division Multiple Access (FDMA): the available spectrum is split into a number of distinct parts (channels) each large enough to accommodate a single user or call without overlap, all users utilize their channel 100% of the time for the duration of the call or message. The channels are normally of equal bandwidth
- Time Division Multiple Access (TDMA): the available spectrum is allocated to a single channel, each user or call assigned a certain portion of time
- Code Division Multiple Access (CDMA): the available spectrum is allocated to a single channel, each user or call is assigned a unique sequence code to spread the message over the available spectrum. All users use the whole of the spectrum all of the time. At the receiver, the same unique sequence code is used to recover the desired signal from the sum of all the user calls.

2G systems used a combination of FDMA/TDMA for GSM or various versions of CDMA, for example, cdmaOne (IS-95). While the 2G technology continues to operate, subsequent third and fourth generations of network technologies were introduced in 1998 (3G), 2006 (4G), and 2011 [4G-Long Term Evolution (LTE)]. These technologies were developed to support increased data demands for multimedia access with increased bandwidth and transfer rates to accommodate internet-based broadband applications, including video conferencing, streaming video, sending and receiving faxes, and downloading e-mail messages with attachments. With the introduction of 3G technology, “smartphones” were developed. With these devices, the newer technologies were overlaid with 2G to support multiple access modes (2G, 3G, and 4G)[2]. Although the 2G technologies will be phased out over time and replaced by newer technologies, the current wireless communication networks continue to utilize 2G for voice and text.

All 3G systems utilize CDMA/WCDMA technology and fall into two groups complying with the 3rd Generation Partnership Project (3GPP) or 3GGP2 family of standards. Universal Mobile Telecommunications Service (UMTS), Wideband Code Division Multiple Access (WCDMA), and Time Division-Synchronous Code Division Multiple Access (TD-SCDMA) are 3GPP variants, CDMA2000 (which is based on 2G cdmaOne) is 3GPP2. 4G systems use Orthogonal Frequency Division Multiplexing (OFDM) within the E-UTRAS (LTE-Advanced) or Worldwide Interoperability for Microwave Access (WiMAX) standards.

Modulation Schemes (GSM and CDMA)

The Global System for Mobile Communications (originally *Groupe Spécial Mobile*; GSM) was developed to establish a digital standard for compatibility throughout Europe. GSM is a circuit-switched system that uses both FDMA and TDMA technologies. The frequency division mechanism divides the GSM band into 200 kHz-wide channels. The time division mechanism enables up to eight different time slots (voice channels) per frequency channel wherein a single cell phone transmits in only one out of eight available time slots during a voice communication. This introduces a pulsed signal shape with a pulse repetition rate of 217 Hz. Such a TDMA

frame has a length of 4.6 milliseconds (ms) (Figure 2), and 26 TDMA frames make up a multiframe with a 120 ms duration (Figure 3). During a multiframe, a mobile phone transmits in 25 out of 26 possible time slots. This TDMA frame structure causes significant low frequency amplitude modulation components to be superimposed on the RF carrier at 8.3 and 217 Hz. Furthermore, as a direct consequence of the TDMA, the peak power and instantaneous SARs are 8.3 × higher than the average power and SAR; note that the average power is the metric of importance for SAR determination within the context of the current safety standards.

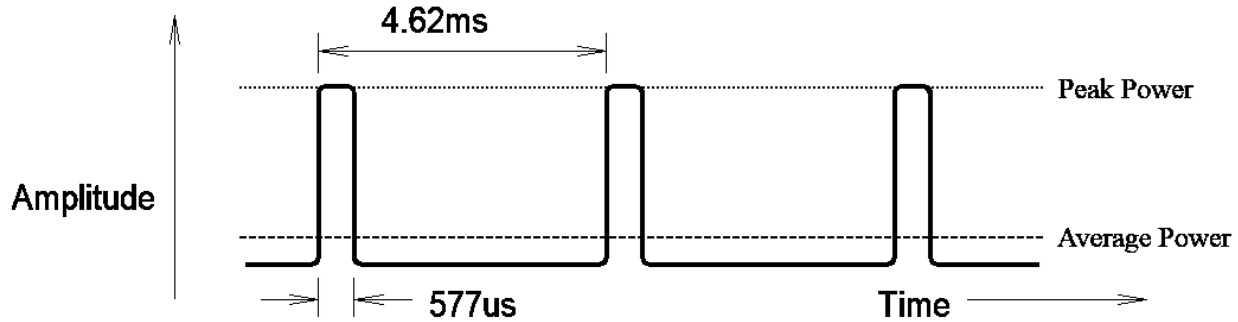

Figure 2. GSM Frame Showing Peak and Average Transmit Powers

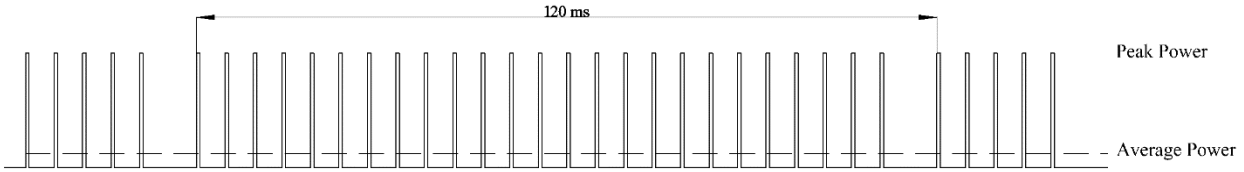

Figure 3. GSM Multiframe Showing the Missing 26th Frame

With GSM, the duplexing between uplink (when the handset transmits to the base station) and downlink (when the base station transmits to the handset) is implemented in the frequency and time domain. Constant frequency spacing is maintained between up and downlink frequencies; in the United States the uplink is 1,850 to 1,910 MHz, and the downlink is 1,930 to 1,990 MHz. The uplink and downlink frequencies are chosen according to the cell (area that is covered by a base station) into which the mobile is registered. In order to minimize interference between neighboring cells, a frequency reuse policy is applied. In this approach, when a mobile phone moves from one cell into an adjacent cell, frequencies used for data uplink and downlink change in association with this movement (i.e., transmission frequencies change at handover from one cell to another).

CDMA technology uses a form of coded transmission known as Direct Sequence Spread Spectrum (DSSS) in which data are multiplied by a much faster pseudo random code before being modulated on to the carrier. The effect of the multiplication is to spread the message across the whole frequency bands available for use at a given time in a given cell, but with very specific characteristics. CDMA signal access technology is based on code division separation of mobile stations as well as base stations. This implies differences of the signal structure compared to GSM. For example, in IS 95 in the forwardlink (downlink), a set of 64 Walsh codes (which are deterministic and orthogonal) are applied to spread/separate the individual channels in the

downlink of a cell. After the orthogonal spreading, a short (16-bit) Pseudo Noise (PN) code is applied to further spread the signal and identify the cell. Hence, a separation of neighboring cells in the frequency domain is no longer necessary, and there is no need for the mobile station to change its transmission frequency during the transition from one cell into another. As with GSM systems, the duplexing between the forward and reverse links is implemented in the frequency domain. In CDMA systems, an efficient power control is crucial. Because all mobile stations transmit and interfere in the same frequency channel, each mobile device decreases the signal to noise ratio of all the other mobile devices. Hence, the output power of a mobile phone should be kept at a minimum that guarantees good transmission quality.

IS-95, also known as cdmaOne, was developed by Qualcomm (San Diego, CA) as the first 2G CDMA-based digital cellular technology. The term IS-95 generally applies to a protocol revision (P_REV=1) that was adopted as a standard (TIA-EIA-95) by the Telecommunications Industry Association (TIA) in 1995. Over time, subsequent iterations of the IS-95 protocol such as IS-95A, TSB-74, and IS-95B were developed, each with incremental improvements over the previous protocols. Later, more advanced versions of the CDMA technology have evolved to include IS-2000, which incorporated much higher transfer rates than the previous 2G versions. For a further explanation of these technologies and how the NTP exposure system was designed to reproduce similar GSM and CDMA cell phone RFR exposures please see the video presentation[a] (day 1 a.m. at 54 minutes) by Dr. Myles Capstick[3].

Sources, Use, and Human Exposure

The predominant source of exposure to RFR for the majority of the population is through use of telecommunications and mobile internet access applications for wireless devices, and the highest human exposure to cell phone RFR occurs through the use of cellular phone handsets and other wireless devices such as tablets and laptop computers held in close proximity to the human body. Aside from telecommunications, there are other man-made applications of RFR, which include microwave ovens, radar, industrial heating and sealing, medical diagnostics [Magnetic Resonance Imaging (MRI)] and therapy (surgical diathermy and ablation), and remote tracking or detection of objects [anti-theft, Radio Frequency Identification (RFID)]. There are also natural sources of RFR such as atmospheric electrical discharges (lightning) and solar and cosmic radiation. RFR exposures from natural sources are much smaller and tend to be spread over a much wider range of frequencies compared to exposures to fields from man-made radiation sources[4].

The use of cell phones has become widespread over the last two decades, and concern has been expressed regarding the potential health risks associated with use specifically by children. According to a Pew Research poll[5], approximately 95% of adult Americans own a cell phone. As of December 2015, the number of active wireless subscriber connections was 377.9 million, which exceeded the population of the United States[6]. According to the same survey, 49.3% of households in the United States utilize only a wireless phone, and not a landline.

There has been a great deal of focus on the possibility of increased risk of brain cancer because of the traditional use of these devices in close proximity (0 to 2 cm) to the head. In general (apart from the case when very close to the antenna), the level of RFR exposure from a cell phone is

[a] https://doi.org/10.22427/NTP-VIDEO-41

inversely proportional to the square of the distance of the body from the device's antenna, resulting in the highest SAR levels in the parts of the body nearest to the antenna.

Accurate and detailed measurements of RFR exposure in humans are difficult to estimate because the output power of wireless devices constantly varies depending on several factors. Overall, the network carrier adjusts the output power of each connected device to the lowest level that is still compatible with a good quality signal. This adaptive power control occurs continuously and is achieved by a logarithmic downscaling of the time-averaged power from the maximum of 0.125 or 0.25 W to a level as low as 1 mW. When in use, the output power (and subsequent exposure to cell phone RFR) from the device is increased compared to that in "standby" mode. Therefore, exposures are related to the amount of active time a user spends on the device. The output power of a device changes based on the signal received at the base station. Decreases in signal strength result in higher output powers. Therefore, there are increases in the output power as the distance between the device and the base station increases, if there are physical obstacles between the device and the base station, reflections off buildings or other structures, and during handovers from one cell to another in the case of GSM. The proximity of the device to the body and the type, number, and position of antennas in the device are other important factors affecting the amount of exposure to RFR.

Potential exposure to RFR used in cell phones also occurs from the cell phone towers that form the network. While modern towers emit substantially more power than devices, exposures from base station antennas are considerably lower to users than from the handheld device. Typically, base station antennas are placed at heights of 50 to 200 feet, in order to adequately cover a cell. The antennas direct RF energy toward the horizon, with some downward tilt. As with all forms of radiation (ionizing and nonionizing), the RF energy level decreases rapidly as the distance from the antenna increases. As a result, the level of exposure to RFR at ground level is very low compared to the level close to the antenna.

Some base station antennas are installed on rooftops and at the top of lamp poles that are in close proximity or adjacent to office space and residential buildings. Occupational exposure can occur during maintenance of base stations. As a result, the FCC established guidelines for occupational exposures. Safety guidelines and regulatory compliance are discussed below.

The levels of RFR inside buildings with base station antennas mounted on the roof or on the side of the building are typically much lower than the level outside, depending on the construction materials of the building. Wood or cement block reduces the exposure to RFR by a factor of about 10. Due to the directional nature of the signals, the energy level behind an antenna is orders of magnitude lower than in front of the antenna.

Safety Guidelines for Exposure

The FCC and U.S. Food and Drug Administration (FDA) are jointly responsible for the regulation of wireless communication devices.

Federal Communications Commission

The FCC is required by its responsibilities under the National Environmental Policy Act of 1969 to evaluate the impact of emissions from FCC-regulated transmitters on the quality of the human environment (42 USC §4321 et seq.). As a result, the FCC regulates both the wireless devices as well as the base stations. Since 1996, the FCC has required that all wireless communication

devices (transmitting in the 100 kHz to 6 GHz frequency range) sold in the United States comply with its minimum guidelines for safety and maximum RFR absorption standards based on SAR. The FCC requires a formal approval process for all devices sold in the United States. FCC approval is contingent on the demonstration that the device does not exceed the maximum allowable SAR level when the device is operating at its maximum power. The SAR limit adopted by the FCC for exposure in the general population is 0.08 W/kg, as averaged over the whole body (wbSAR), and a peak spatial-average SAR (psSAR) of 1.6 W/kg, averaged over any 1 gram of tissue[7] when averaged over 6 minutes. Exceptions are made for the extremities (hands, wrists, feet, ankles, and pinnae), where the psSAR limit is 4 W/kg, averaged over any 10 grams of tissue for an exposure period of no longer than 30 minutes. For occupational exposures, the wbSAR limit is 0.4 W/kg, and the psSAR limit is 8 W/kg, averaged over any 1 gram of tissue. For the hands, wrists, feet, ankles, and pinnae, the psSAR limit for occupational exposure is 20 W/kg, averaged over any 10 grams of tissue for an exposure period not to exceed 6 minutes.

The FCC rules and guidelines for cell phone RFR exposure are based upon standards initially developed by the Institute of Electrical and Electronics Engineers (IEEE) and the National Council on Radiation Protection and Measurements (NCRP). These standards for RF exposure in workers and the general population are based on protection against adverse effects that might occur due to increases in tissue or body temperature in excess of 1° C (wbSAR, approximately 4 W/kg) or less (after applying safety factors). Because RF-energy absorption and any induced effects are dependent on the frequency of incident-field parameters and the composition of exposed tissues, it has been suggested that quantifying SARs in small averaging regions is more relevant for evaluations of human health effects.

Food and Drug Administration

The FDA does not currently regulate the use of wireless communication devices or the devices themselves. The FDA also does not require safety evaluations for radiation-emitting wireless communication devices. It does maintain the authority to take regulatory action if it is demonstrated that exposure to the emitted cell phone RFR from these devices is hazardous to the user.

Absorption of RFR

RFR interacts with the human body via inductive or capacitive coupling or a combination of both. The absorption of the coupled RFR is dependent on the frequency of the signal and the dielectric properties of the exposed tissue. It generates oscillating currents in the tissue, which in turn give rise to induced E-fields. The energy is transferred into molecular motion of polar molecules like water, a strongly dipolar molecule and major component of biological tissues. Resonant oscillations in polar subgroups of cellular macromolecules are damped by collisions with surrounding water molecules that disperse the energy of the RF signal into random molecular motion. Tissue heating occurs as the energy is transferred to the surrounding aqueous environment as heat[4].

Toxicity

A comprehensive review of the toxicity of RFR in in vitro models, laboratory animals, and humans was conducted and published in the International Agency for Research on Cancer (IARC) Monograph series[4].

Thermal Effects

Given the ability of RFR to heat tissues, the toxic effects of RFR are often considered due to thermal effects. The most well-established and biologically plausible mechanism for RFR-induced effects is through tissue heating. At sufficiently high levels of RFR exposure, the absorption of energy could overwhelm an organism's ability to thermoregulate and maintain an acceptable body temperature. Typical human exposures to RFR occur at intensities that are not anticipated to cause significant tissue heating if handsets are used according to the manufacturer's recommendations for use, and assuming the phones are not emitting more RFR than permitted by FCC regulations.

Nonthermal RFR effects refer to biological changes that occur with body temperature increases that are below 1° C. Changes of temperature up to 1° C are considered in the range of thermal noise[4]. There is an ongoing debate regarding whether nonthermal biological effects can occur as a result of exposures to low-intensity RFR. It has been suggested that there is no plausible nonthermal mechanism by which exposure to low-intensity RFR could induce significant biological effects[8-10]. However, there are numerous reports of specific biological effects associated with RFR exposures at levels considered below those expected to result in a measurable amount of tissue heating. Other than tissue heating, the mechanisms of interaction between cell phone RFR and biological systems have not been well characterized, but several mechanisms have been proposed, including the generation of reactive oxygen species, induction of ferromagnetic resonance, and the alteration of ligand binding to hydrophobic sites in receptor proteins[4]. Additionally, low levels of exposure to RFR may result in small temperature changes in localized areas of exposed tissues that cause conformational changes in temperature-sensitive proteins and induce the expression of heat-shock or stress-response proteins.

Experimental Animals

Toxic effects have been reported in RFR-exposed laboratory animals and in vitro systems[4; 11]. Many studies investigating the potential toxicity of RFR have focused on genotoxicity and related effects and are reviewed in the Genetic Toxicity section. However, studies have been conducted to evaluate a variety of other aspects of toxicity, particularly those potentially related to cancer development or surveillance, including specific studies on gene and protein expression, immunotoxicity, and permeability of the blood-brain barrier. The results of these studies have not led to a clear understanding of the interactions of RFR with biological systems, but it is important to note that many of these studies were conducted with RFR of differing parameters (frequency, power density, continuous wave versus amplitude-modulated signals, etc.).

Several effects on the humoral and cell-mediated responses of the immune system have been reported at various frequencies of RFR in rats and mice. These include effects on the activity of NK cells, plaque-forming cell response to sheep erythrocytes, production of tumor necrosis factor (TNF) in peritoneal macrophages and splenic T-cells, mitogenic response in T lymphocytes, phagocytic activity of neutrophils, leukocyte profile, and thymic and splenic cellularity[12-17]. However, many of these effects were observed in studies conducted with RFR at frequencies greater than 10 GHz. Other studies have demonstrated no exposure-related effects on the immune system[16; 18-22].

A few studies have investigated the impact of RFR at frequencies between 800 and 1,900 MHz on gene and protein expression. Several studies have demonstrated that RFR can alter the

expression of certain genes in the brain[23-25], while others have failed to find changes in gene expression[26-28]. The expression of various proteins has also been investigated in rats and mice. These studies have primarily yielded negative results for the specific proteins being evaluated in the rat brain[23; 24; 29-31]. Similarly, no effects of RFR on protein expression have been reported in the testis[32] or in the skin[33-35]. Liu et al.[36] reported adverse effects on sperm following exposure for 2 hours/day to 900 MHz RFR at 0.66 W/kg for 50 days. Changes in the expression of bone morphogenic protein and bone morphogenic protein receptors have been reported in the kidney of newborn rats[37]. A study by Eşmekaya et al.[38] also demonstrated increased expression and activity for caspase 3 and caspase 9 in the thyroid gland of Wistar rats. Ohtani et al.[39] observed induction of expression of some heat shock protein genes in the cerebral cortex and cerebellum of rats exposed to 2.14 GHz of WCDMA RF at 4W/Kg, but not in rats exposed for 3 hours, or for 3 or 6 hours to 0.4 W/Kg.

Exposure to RFR induces changes in markers for oxidative stress in multiple tissues, including the brain[29; 40-43], heart[44], kidney[45; 46], eye[47], liver[48; 49], endometrium[50; 51], and testis and epididymis[52]. Yakymenko et al.[53] reviewed oxidative mechanisms reported in a number of in vitro and in vivo experiments with “low intensity” RFR. A few studies have also demonstrated RFR-mediated effects on differentiation and apoptosis in the endometrium[50; 51] and brain[31; 54]. Changes have also been noted in the permeability of the blood-brain barrier in some studies[55-57]. However, other studies conducted under similar experimental conditions failed to demonstrate any effect of cell phone RFR exposure on the permeability of the blood-brain barrier[58-61].

Humans

Numerous epidemiology studies have investigated the association between exposure to RFR and health effects in humans. However, many of these studies examined small groups exposed to RFR signals with different characteristics (frequencies, modulations, intensities, etc.) such as microwaves, extremely low frequency (ELF) fields, and radar rather than the specific frequency bands and modulated RFR signals used in wireless communication.

There is limited research investigating the general toxicity of RFR in humans because most of the focus has been on the potential for carcinogenic effects. There are reports of exposed individuals that complain of acute, subjective effects following exposure to RFR, including headaches, fatigue, skin itching, and sensations of heat[62-67]. These have primarily been reported in people that consider themselves electrosensitive. It has been suggested that there are likely other causes, not RFR, for these subjective symptoms[68]. Variable results have been observed in the electroencephalogram (EEG) of volunteers exposed to RFR during sleep. Some studies indicate that exposure to RFR induces changes in sleep latency and sleep EEG[69-79]. Glucose metabolism in the brain, a marker for metabolic activity, is increased in the region of the brain closest to the antenna[80]. While these results demonstrate exposure-related effects, the toxicologic significance of these findings is unclear.

Carcinogenicity

A comprehensive review of the carcinogenicity of RFR in laboratory animals and humans was conducted and published in the IARC Monograph series[4]. Additional reviews of animal cancer studies have been published by Lin[81], and of human studies by Repacholi et al.[82] and Yang et al.[83]

Experimental Animals

Studies published to date have not demonstrated consistently increased incidences of tumors at any site associated with exposure to RFR in rodents[81]. No increases in tumor incidences were observed in B6C3F1 mice exposed to GSM-modulated RFR for 24 months[84], F344 rats exposed to CDMA-modulated RFR for 24 months[85], or Wistar rats exposed to GSM-modulated RFR for 24 months[86]. In studies conducted in transgenic and tumor-prone mouse strains, exposure to RFR has not been consistently associated with an increased incidence of tumors at any site[87-91]. While these studies have advanced the knowledge of the potential toxicity of RFR, critical limitations in the design of many of these studies severely limit the utility of the information to adequately evaluate the carcinogenicity of RFR. These limitations include studies with very short daily exposure durations (≤ 2 hours per day) in heavily restrained animals or with levels of RFR exposures too low to adequately assess carcinogenic potential. The focus of many of these studies conducted in genetically altered and tumor-susceptible mice was not to evaluate the overall carcinogenicity of RFR, but to investigate the effects in the specific predisposed tissues in that model.

Based on the constraints in the designs of the existing studies, it is difficult to definitively conclude that these negative results adequately establish that RFR is not carcinogenic. To adequately evaluate the potential chronic toxicity and carcinogenicity of RFR, further studies with enhanced study designs and improved exposure paradigms were needed.

Humans

As a result of the IARC review conducted in 2011, RF electromagnetic fields were classified as possibly carcinogenic to humans (Group 2B). This classification was based on limited evidence of carcinogenicity in humans based on positive associations between exposure to RFR from wireless phones and increased risk for gliomas and acoustic neuromas, specifically in users with the greatest amount of cell phone usage. The IARC Working Group acknowledged that the findings were affected by potential selection and information bias, weakness of associations, and inconsistencies between study results[92].

While several other studies were considered, the IARC evaluation was based primarily on reports from the INTERPHONE Study, the largest research effort conducted to date examining the potential association between exposure to RFR and cancer in humans. INTERPHONE was an IARC-coordinated research effort that included a series of studies conducted with a common core protocol at 16 study centers in 13 countries: Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden, and the United Kingdom[93]. The studies were specifically designed to investigate the association between RFR and tumors of the brain (glioma and meningioma), acoustic nerve (schwannoma), and parotid gland. The final report for the INTERPHONE studies was published in 2011[92].

The results of these studies seemingly demonstrated an elevated risk of glioma and acoustic neuroma in the group in the highest decile for exposure (cumulative phone call time). However, the INTERPHONE study group concluded that recall and selection biases and implausible values for usage reported by the participants in the study may explain the increased risk[94; 95].

Other studies have compared time trends in cell phone usage and the incidences of different types of cancers to investigate indirect evidence of an association between RFR used in cell

phones and cancer. These studies were conducted across several different countries[96], and in a group of European countries[97-101], the United States[102-104], Japan[105], New Zealand[106], and Israel[107]. Overall, the evaluations suggest that there was no significant change in the trends of cancer incidences. Any increases in cancer rates that were observed in these studies were attributed to enhanced detection capabilities for cancer that were the result of advances in diagnostic medical equipment, like computerized tomography (CT) scans and MRI.

Several cohort studies have been conducted, but also failed to establish a clear association between cell phone RFR and the development of any of the investigated cancer types[108-110]. Additional studies have demonstrated that there was no association between cell phone usage and pituitary gland tumors[111; 112], testicular tumors[109; 113], parotid gland tumors[114; 115], uveal melanoma in the eye[109; 116], and cutaneous melanoma[117]. Some studies have demonstrated that there was no association between cell phone usage and leukemia[108; 109] and non-Hodgkin's lymphoma[118], whereas others have reported increased risk of non-Hodgkin's lymphoma[119] and leukemia[120].

Since the 2011 IARC Working Group evaluation, few additional epidemiological studies have examined mobile phone use and risk of cancer. A case-control study of children and adolescents from four European countries did not find an association between overall mobile phone use with brain cancer[121]. A pooled analysis of multiple Swedish case-control studies by Hardell, Carlberg and colleagues found a significant increased risk of glioma and acoustic neuroma, particularly among analog phone, ipsilateral, and long-term or high frequency mobile phone users[122-124]. No increased risk of meningioma was found with overall mobile phone use[122; 125]. Other case-control studies did not report an increased risk of glioma[126; 127] or meningioma[128] with regular mobile phone use; however, Coureau et al.[126] did find a significant increased risk of glioma and meningioma with heavy mobile phone users. A prospective cohort study of UK women did not find an association with glioma, meningioma, or acoustic neuroma[129; 130].

Numerous systematic reviews of the epidemiology literature database have been conducted in addition to the 2011 IARC evaluation, with conflicting conclusions. Available systematic reviews have found an association between cell phone use and increased risk of brain tumors[122; 131], while other reviews did not find an association with brain tumors[82; 132]. These contrasting results have been considered possibly due, in part, to differences in study eligibility criteria, the number of studies included, when the review was conducted, and how studies were evaluated[133].

Genetic Toxicity

Extensive reviews of the literature on the genotoxicity of various frequencies and modulations of RFR, covering experimental systems ranging broadly from cell-free DNA preparations to cells of exposed animals and humans, have concluded that evidence for cell phone RFR-associated genotoxicity is inconsistent and weak[82; 134-136]. Interpretations of the genotoxicity studies and the ability to draw definitive conclusions based on weight-of-evidence from the large number of studies that have been reported have been hampered by inadequacies in experimental design, especially related to exposure standards and radiation-measuring procedures[134]. Although the majority of studies report a lack of effect, the several reports of a positive response are concentrated among experiments assessing chromosomal or DNA damage in mammalian cell systems in vitro and in vivo. Some key studies reporting RFR-associated genotoxicity in human

cell lines, including DNA damage and chromosomal effects, could not be replicated[137; 138]. A critical complicating factor in the study of the genotoxic effects of cell phone RFR is that under certain conditions, RFR is sufficiently energetic to heat cells and tissues, and not all studies have considered this factor in their design. Heating of cells in vivo and in vitro has produced positive results in tests for genotoxicity, such as the comet assay and micronucleus assay[139-141]. The mode of action whereby heat induces these effects may be through induction of protein denaturation and aggregation, which can interfere with chromatin structure and slow the kinetics of DNA repair or interfere with mitosis by disrupting microtubule function[142; 143]. Thus, heat-induced increases in DNA migration seen in the comet assay may reflect slowed repair of endogenous lesions, and similarly, activity in the micronucleus assay may be due to aneugenic rather than clastogenic events[139-141]. Therefore, it is important to control thermal conditions when studying measures of genotoxicity following exposure to cell phone RFR.

Study Rationale

The FDA nominated cell phone RFR emissions of wireless communication devices for toxicology and carcinogenicity testing. Current exposure guidelines are based on protection from acute injury from thermal effects and little is known about the potential for health effects from long-term exposure to RFR below the thermal hazard threshold. Epidemiology studies that have been conducted to date have demonstrated possible, but not yet causal links between cell phone RFR and some health problems in humans, however the results of these studies are complicated by confounding factors and potential biases. Additionally, exposures in the general population may not have occurred for a long enough period to account for the long latency period of some types of cancers in humans. Similar to the challenges faced in epidemiological studies, studies in laboratory animals have been complicated by limitations that researchers have faced in conducting robust studies designed to characterize the toxicity and carcinogenicity of cell phone RFR.

For years, the primary concern regarding the potential health risk of chronic exposure to cell phone RFR was brain cancer based on the proximity of wireless devices near the head during use. While the brain is an organ of concern, understanding the potential toxicity and carcinogenicity of whole-body exposure is critical. RFR is constantly emitted from wireless devices to communicate with base stations, regardless of whether the user is on a call or not. As the public has become more aware of the uncertainty regarding the potential effects of RFR on the brain, more emphasis has been placed on the use of wired or wireless headsets (like Bluetooth), which minimize RFR exposure to the head. In recent years, the density of cell towers has increased to cope with the increasing demand for capacity, resulting in installations closer to residential neighborhoods and schools. Additional RFR technologies, like SmartMeters used by power companies, transmit data in real time using RFR. These existing and emerging technologies may potentially increase the level of exposures in human populations. These and other additional sources also expose different parts of the body, not only the head.

In 2011, RFR was classified by the IARC as possibly carcinogenic to humans based on limited evidence of an association between exposure to RFR from heavy wireless phone use and glioma and vestibular schwannoma (acoustic neuroma) in human epidemiology studies and limited evidence for the carcinogenicity of RFR in experimental animals[4]. While ionizing radiation is a well-accepted human carcinogen, theoretical arguments have been raised against the possibility that nonionizing radiation could induce tumors (discussed in IARC[4]). Given the extremely large

number of people who use wireless communication devices, even a very small increase in the incidence of disease resulting from exposure to the RFR generated by those devices would translate to a large number of affected individuals, which would have broad implications for public health. Due to the changing exposure patterns and use of cell phones by pregnant women and women of childbearing age, RFR exposures to the whole body and exposures during the perinatal period (rat studies only) were selected for inclusion in these studies.

In the current studies, male and female B6C3F1/N mice were exposed to GSM or CDMA RFR at 1,900 MHz for 9 hours and 10 minutes per day, 7 days per week, over the course of 18 hours and 20 minutes, in 10-minute-on, 10-minute-off intervals for 28 days or 2 years. Exposures began when the animals were 5 to 6 weeks old, and were to 0 (sham control), 5, 10, or 15 W/kg in the 28 day studies or 2.5, 5, or 10 W/kg in the 2-year studies for each modulation. Exposure energy levels were selected based on pilot studies of body temperature changes from these RFR power levels reported in Wyde et al.[144]. The selection of 1,900 MHz for the frequency for the mouse studies was based on dosimetry studies by Gong et al.[145], and the video[b], day 1 a.m. at 2 hours, 37 minutes.

[b] https://doi.org/10.22427/NTP-VIDEO-41

Materials and Methods

Overview

The establishment of the National Toxicology Program (NTP) research program on radio frequency radiation (RFR) has required the coordination of expertise from multiple scientific and engineering disciplines. At the initiation of the RFR research program, a collaboration was established with technical experts from the Radio-Frequency Fields Group in the Radio Frequency (RF) Technology Division, which is part of the Communications Technology Laboratory (CTL) at the National Institute of Standards and Technology (NIST, Boulder, CO). NIST evaluated the existing exposure systems and identified the types of improvements that would be required to provide a system of sufficient size and power to conduct robust toxicology and carcinogenicity studies with uniform RFR exposures in unrestrained, individually housed animals for a minimum of 6 hours a day at frequencies and modulations that reflected those in use at the time. The design of the chambers and toxicology studies required special consideration of logistical, financial, and engineering limitations.

NIST tested the feasibility of a reverberation chamber-type exposure system by conducting a series of studies on field strengths, field uniformity, and power requirements under various conditions of RFR exposure in such chambers. These studies provided critical information for the design of experimental studies with respect to the number of cages that could be placed in specific size chambers, the arrangement of cages within each chamber, and the input power requirements.

Concurrent with the collaboration with NIST, NTP also worked with the Foundation for Research on Information Technologies in Society (IT'IS, Zurich, Switzerland), which conducted studies using computational models that simulated RFR dosimetry to provide estimates of whole-body and organ-specific internal field strengths and specific absorption rates (SARs) during exposure. Based on information and parameters obtained during the NIST feasibility studies, IT'IS built a prototype reverberation chamber as the basis for an exposure system to study health effects of long-term exposure of laboratory animals. Following completion, NIST evaluated the prototype exposure chamber to determine if it met the requirements specified by NTP.

The role of each institution collaborated with is outlined below:

- National Institute of Standards and Technology (NIST), Boulder, CO.
    - Suggested reverberation chamber exposure system.
    - Conducted feasibility studies for reverberation chambers.
    - Established various technical parameters for chambers.
    - Evaluated the prototype chamber built by IT'IS Foundation.
    - Validated the system prior to the conduct of studies at IITRI.
    - Reevaluated RFR exposures prior to and after 2-year studies.
- IT'IS Foundation, Zurich, Switzerland.
    - Constructed and tested prototype chamber.
    - Refined technical parameters.

    - Built the chambers for the NTP exposure facility.
    - Installed chambers at IITRI.
    - Monitored system performance throughout all phases of the studies.
    - Conducted maintenance on exposure system hardware and software.
- IIT Research Institute (IITRI), Chicago, IL.
    - Tested exposure system after installation.
    - Conducted maintenance of exposure system hardware.
    - Conducted all toxicology and carcinogenicity studies.

Conducted day-to-day operations.

After prototype-testing by IT'IS Foundation and NIST, the IT'IS Foundation built the reverberation chambers required for the NTP RFR exposure facility. Chambers were installed at the Illinois Institute of Technology (IIT) Research Institute (IITRI, Chicago, IL). Following the installation and initial testing of the exposure system by IT'IS and IITRI, technical experts from NIST conducted an independent validation of the system. NIST confirmed that the probe readings in the system were consistent, that field uniformity was within expected specifications, and that the signal quality was acceptable. NIST performed additional evaluations prior to initiation of the 2-year studies and after completion of the studies to determine if any changes occurred in the signal quality, field uniformity, or consistency of in-chamber field measurements. All studies were conducted at IITRI with real-time monitoring of the system performance at IT'IS Foundation.

Reverberation Chamber Method of Exposure

The use of the reverberation exposure chamber as a method for exposing rats and mice to cell phone RFR was conceptualized by NIST and further designed and tested by NIST and the IT'IS Foundation. A reverberation chamber is a resonant box where the resonances and field structure are continuously modified under the influence of metallic stirrers, introduced to change the effective geometry, such that when averaged over time, the field strength is uniform over the entire exposure volume. A reverberation chamber exposure system was selected by NTP for the primary benefit that controlled exposures can be achieved in unrestrained animals (rats and mice) with extended daily RFR exposure periods compared to other methods of exposure for up to 2 years.

Preliminary studies were first conducted at NIST to test the concept of reverberation chambers. In these studies, field strengths and field uniformity were measured under various conditions of RFR exposure, including an empty chamber and a chamber loaded with water bottles (simulating animals) at different locations in the chamber. Power requirements were evaluated to achieve desired SAR levels. The effects of proximity between water bottles were also investigated to avoid electromagnetic coupling. These studies provided critical information for the design of experimental studies with respect to the number of cages that could be placed in specific size chambers, the arrangement of cages within each chamber, and the input power requirements. The results of these investigations demonstrated that while variations occurred over time and space the average RFR field was uniform over the large volume of the chamber. These studies also demonstrated that RFR field exposure occurred from all directions and all polarizations, and that there was uniformity of SAR in reverberation chambers. Based on the information and

parameters obtained during the NIST feasibility studies, a custom-built prototype reverberation chamber was constructed and tested by the IT'IS Foundation. The development of the prototype chamber involved the design of amplifiers and antennas for signal generation, the design of vertical and horizontal stirrers to improve the homogeneity of experimentally generated RF fields, the development of both hardware and software for the control and monitoring of experimentally generated RF signals, and testing of chamber performance. During the design of the prototype exposure chamber, engineering studies were performed to optimize the following prior to construction:

- The uniform field volume within each chamber to minimize spatial variability in the characteristics of generated RF fields within a chamber such that all animals housed within the chamber space were exposed to comparable RF field strengths.
- The design and placement of stirrers in each chamber in order to maximize homogeneity of experimentally-generated RF fields.
- The design and location of RF antennas in each chamber.
- The location of cage racks within the exposure chamber in order to provide appropriate separation of individual animal cages and cage racks from all reflective surfaces (chamber walls, chamber floor and ceiling, antennas, and stirrers) in the reverberation chamber.
- Chamber volume to provide adequate space for staff to observe animals, collect data, and perform routine animal husbandry operations, while minimizing overall chamber volume to minimize the chamber size/footprint and the RF power required to maintain target SARs.

The final reverberation chamber design for use in these studies was a fully-shielded room constructed of stainless steel, equipped with a shielded room door to eliminate leakage of RFR signals, two rotating stirrers (one horizontal and one vertical), ventilation structures, and RFR excitation antennas. A detailed rationale for the selection of reverberation chambers for exposure to RFR and a full description of the exposure system are provided in Capstick et al.[146] and Gong et al.[145] and in a video[c] (day 1 a.m. at 54 minutes) on the NTP website[3].

As part of the validation of the reverberation chamber exposure system design, a team of engineers from NIST conducted an independent evaluation of chamber design and exposure system operation in order to evaluate the suitability of the reverberation chamber model for use in the program. NIST engineers evaluated the design and operation of the prototype chamber and performed an extensive series of RF measurements to support an evaluation of system performance. Further information on the exposure verification is found in the video[d] (day 1 p.m. at 0 minutes) by John Ladbury[3].

RFR Exposure Facility

The exposure facility was specifically designed to expose mice in reverberation chambers to three different power levels of modulated cell phone RFR [Global System for Mobile Communications (GSM) or Code Division Multiple Access (CDMA)] at 1,900 MHz for up to

[c] https://doi.org/10.22427/NTP-VIDEO-41

[d] https://doi.org/10.22427/NTP-VIDEO-42

2 years to evaluate toxicity and carcinogenicity. The completed exposure facility consisted of a total of 21 RFR reverberation exposure chambers (seven designated for mice); the RFR signal generation, amplification, and monitoring systems; software for chamber operation; and hardware and software for monitoring of environmental and exposure conditions within each chamber. All system hardware and software were installed by the IT'IS Foundation.

During exposures, modulated (GSM or CDMA) RFR signals were generated by a signal generator, amplifiers amplified the signals, and the signals were delivered by antennas in the reverberation chambers. RFR field strengths were monitored in real time and were adjusted throughout the studies to achieve specific exposure levels [based on SARs quantitated in watts (W) per kg body weight]. Environmental conditions were also monitored and controlled in real time throughout the study. RFR exposures and environmental conditions were monitored and controlled by a computer in a control room at the study laboratory at IITRI; the IT'IS Foundation was also capable of remote system monitoring and control.

Facility Design and Reverberation Chambers

Each reverberation chamber was permanently programmed for a specified modulation (GSM or CDMA) of the 1,900 MHz RFR specified for the mouse studies. Designated SARs for each chamber were selected prior to exposures. The field strengths required to achieve a given target SAR (W/kg) exposure level are a function of animal body weight (kg) and were adjusted to provide consistent SARs as the animals grew. However, separate chambers were not required for male and female B6C3F1/N mice because their body weights and growth curves are sufficiently similar to yield similar SARs. To conduct robust toxicology studies with three exposure groups (low, medium, and high), three chambers were required for different levels of exposures for GSM modulation and three for CDMA modulation. A sham exposure chamber without any RFR signal provided shared control groups for the parallel studies of the two modulations. As per these requirements, the RFR exposure facility consisted of seven reverberation chambers for exposures in mice including:

- Three power levels for mice exposed to GSM-modulated cell phone RFR at 1,900 MHz
- Three power levels for mice exposed to CDMA-modulated cell phone RFR at 1,900 MHz
- One sham control chamber for mice with no RFR exposure

The chamber size was designed to accommodate the RF field stirring paddles (described below), approximately 220 individually housed mice, and a minimum distance (3/4 of a wavelength) between the cages and the walls, floor, ceiling and stirrers, respectively. The interior of the chamber was suitable for cleaning using high-pressure water (after the RF antennas were protected). The internal dimensions of the chambers were 2.2 m (width) × 3.7 m (length) × 2.6 m (height); the exterior dimensions were 2.3 m (width) × 3.8 m (length) × 2.85 m (height). A floorplan for the exposure facility and images of the interior and exterior of the chambers are presented in Figure 4 and Figure 5.

Each chamber contained two motor-controlled stirring paddles (one vertical and one horizontal) with adjustable speed control (1 to 50 rpm) and large asymmetrical reflecting surfaces. Stirring paddles were placed off center in the chamber for maximum scattering of the RFR fields to

generate a statistically homogeneous field distribution when averaged over time. The horizontal stirrer was mounted on the ceiling of the chamber. The vertical stirrer was at the rear of the chamber, and was protected by rack guides that prevented contact with the animal cage racks.

Cage Racks and Watering System

Cages, cage racks, and watering systems for standard laboratory use contain elements that have the ability to alter the exposure of the animals or introduce potential confounding factors. Because cage racks and the drinking water delivery system were contained inside the chambers during exposure periods, it was required that these components be constructed of durable materials that had essentially no impact on the RF fields generated in the chamber. Metallic cage rack components, cage lids, feed dispensers, and cage grommets all needed to be eliminated. Hence, custom engineering was required to overcome the challenges regarding potential RFR exposure-altering aspects of the caging and cage racks used to house the animals during the studies. The safe provision of drinking water provided the largest challenge for the studies.

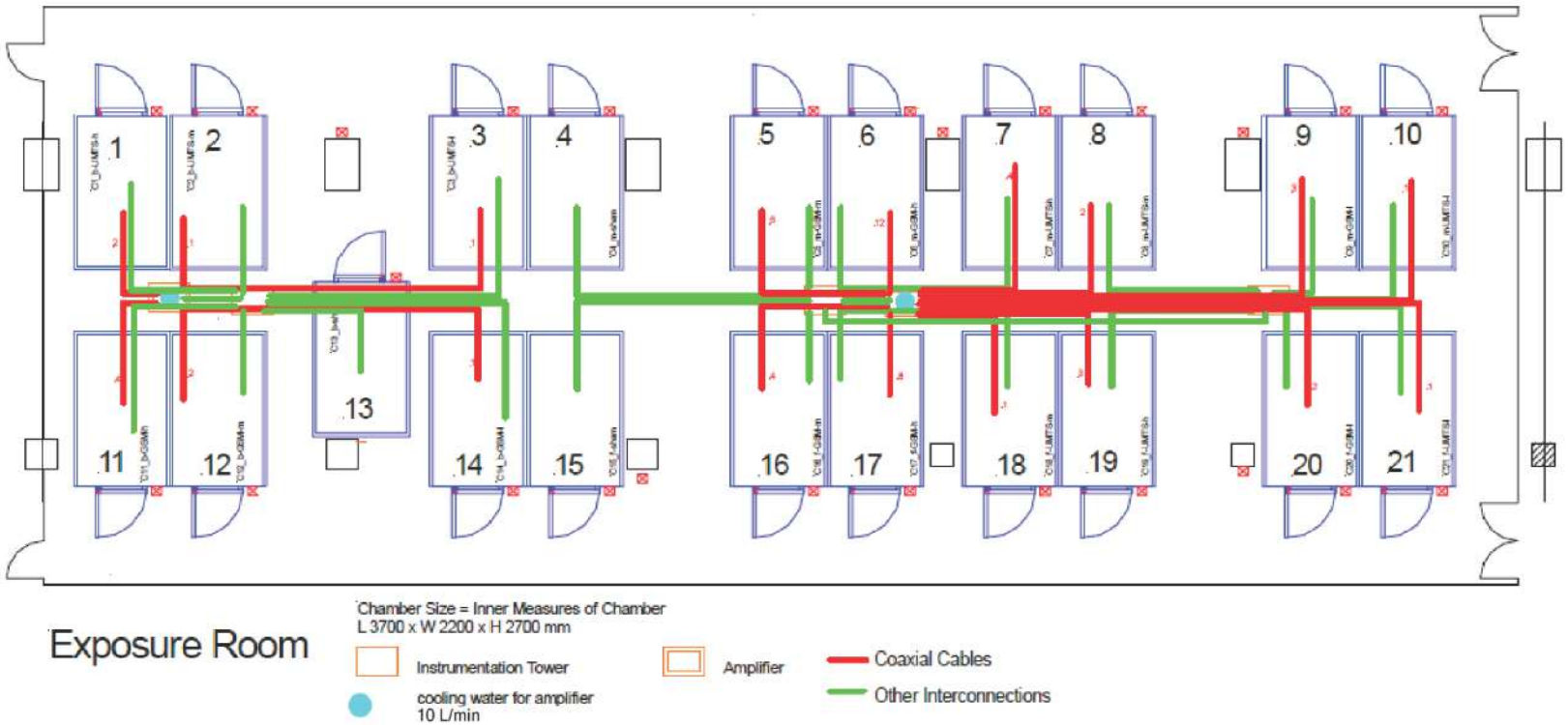

Figure 4. Exposure Facility Floor Plan for the Cell Phone RFR Studies

(Not shown are the Ethernet connections to computers in the control room.)

Mouse chamber designations: low GSM=14; medium GSM=12; high GSM=11; low CDMA=3; medium CDMA=2; high CDMA=1; sham control=13. The 14 other chambers (including 12 for cell phone RFR exposure and two for sham control) were designated for concurrent rat studies.

Figure 5. Exterior View of Chambers, Empty Chamber Showing the Vertical and Horizontal Stirrers, and Chamber with Cage Racks in Place

The absorption of RFR energy by water, if supplied by nonmetallic sipper tubes and distribution systems or bottles, could lead to dose-dependent elevated water temperatures. At the same time, the potential for enhanced exposure fields by metallic sipper tubes or lixits precluded the use of water bottles or a standard automatic watering system in the reverberation chambers. The absorption of RFR energy by water could result in significant heating of the drinking water, thereby decreasing water palatability and increasing the required RFR power to achieve the desired exposure field strength, potentially to the extent that the exposure levels could not be met. To overcome these challenges, adaptations were made to an automatic watering system so that the delivery of drinking water to the animals would not interfere with RFR dosimetry. The water system was constructed from stainless steel ensuring no dose-dependent energy absorption in the water (avoiding exposure-dependent water temperature) and in structures around the lixits to ensure no enhanced fields that could lead to excessive SAR in the animals while drinking.

Customized, nonmetallic animal cage racks for the reverberation chambers were designed by IITRI to minimize any absorption of RFR or disruption of RF field homogeneity. Cage racks were constructed primarily of box beam fiberglass (with some angle beam fiberglass used in nonweight-bearing areas of the rack). The shelves/cage lids were constructed of a clear polycarbonate sheet with slots for increased airflow. The potential impact of the racks on RF fields was evaluated in the prototype reverberation chamber by the IT'IS Foundation. Cage racks were designed to accommodate the automatic watering system and position the perimeter of each animal cage at least one-half wavelength from any reflecting surface. The specific considerations for design and further details of the custom-designed cage racks and adapted automated watering system are provided in Capstick et al.[146] and in the video presentation[e] by Dr. Myles Capstick[3].

RFR Exposure System Control

The hardware and chambers designated for mice (using an exposure frequency of 1,900 MHz) were connected to a dedicated computer control system using an Ethernet protocol. The computerized control system managed and monitored the RFR exposures and environmental conditions in the chambers. A more detailed description of the computer control of RFR exposure is provided in Capstick et al.[146].

The control computer managed the exposure schedule, stirrer rotation speeds, exposure signal and level, and monitored air flow, temperature, humidity, light, and the electric and magnetic fields (E- and H-fields, respectively) in each chamber. The hardware for the exposure system consisted of the control computer and a rack containing communications interfaces and instrumentation for signal generation, data acquisition, signal monitoring, signal amplifiers, and the chamber hardware (which included the stirrer motors and environmental and RFR sensors). The instrumentation rack contained the equipment that generated the RFR signal, acquired RFR field strengths and environmental data, and provided an interface between the components and the control computer.

RFR Signal Generation

GSM-modulated and CDMA-modulated cell phone RFR signals were generated experimentally via a SMIQ02B vector signal generator with options SMIQB11 and SMIQB20 and software

[e] https://doi.org/10.22427/NTP-VIDEO-41

options 100421–100423 (Rohde and Schwarz, Munich, Germany). Signals were amplified using six LSE™ amplifiers (LSE, Spanga, Sweden) in the exposure system. The outputs of each individual amplifier were set by real-time controllers on a slot-by-slot basis for GSM or CDMA modulation to control the E-field strength in each chamber. Each chamber contained at least one standard gain antenna (two half-wave dipoles) that was mounted a quarter of a wavelength in front of a reflector plate. Antennas were directed towards one of the two stirrers to maximize scattering and obtain acceptable E-field homogeneity within the chamber space. The computerized control system managed the exposure schedule, stirrer rotation speeds, and exposure signal type and level.

The RFR power introduced into a given chamber was adjusted to achieve target field strengths; to maintain constant exposure levels (W/kg) in a given chamber, the field strengths [measured in volts (V) per meter] were regularly adjusted to reflect changes in the average mass of the exposed animals. The relationship between animal mass, field strength, and SAR was determined from numerical dosimetry and programmed into the control software, hence the required exposure field strength was computed from the average animal weights entered for each exposure group. The interval at which animal weights were updated was determined on how rapidly the animals were growing, at the start of the exposure period this was once per week, and as long as up to every 4 weeks later in the studies.

Verification of RFR Exposure

Prior to initiation of the animal studies, the RF Fields Group in the Communications Technology Laboratory at the NIST performed an independent, detailed evaluation of each of the reverberation chambers (excluding the sham control chambers; Figure 4) to verify the RFR exposure fields, chamber characteristics (field uniformity), and signal quality to determine the accuracy of field values reported by the developers of the exposure system (IT'IS Foundation). This information provided in the video[f] (day 1 p.m. at 0 minutes) by John Ladbury[3]. Full reports detailing the procedures for measurements and calculations are available from NTP.

All E-field measurements agreed within the estimated uncertainty bounds, indicating that the chamber fields measured by the NIST agreed with the measurements provided by the IT'IS Foundation probes. During validation, it was determined that the H-field probes at higher signal levels in the mid- and high-power GSM chambers reported higher fields than indicated by other measurements, potentially leading to a modest overestimation of chamber field strengths. In these chambers, H-field probes were replaced with E-field probes, which provided more accurate measurements of the RF fields. The magnitude of field variation throughout the volume of a fully loaded chamber was consistent with earlier values reported for the prototype chamber. However, it was determined that there may have been up to ± 2.5 dB of variation in the exposure field depending on location in the cage racks. To mitigate this positional variation, cages were routinely rotated to various locations within and between the cage racks. The quality of the modulated signals was found to be acceptable with regard to distortion and harmonic content.

Overall, the NIST confirmed that the RFR reverberation chamber exposure system was operating correctly and RFR exposures were within specifications.

[f] https://doi.org/10.22427/NTP-VIDEO-42

RFR Exposure Monitoring

During all exposure periods, experimentally generated RFR was continuously monitored by the control system via two RF sensors (E-field and/or H-field probes) in each exposure chamber that measured real-time signal strengths. The use of two probes provided two independent measurements of RF field strengths and ensured that appropriate quantitation of experimentally generated RF fields continued even in the unlikely event that one probe failed. The E-field sensor measured electric field strength (V/m). The H-field sensor measured magnetic field strength [measured in amperes (A) per meter]. All chambers were instrumented with one E-field sensor (ER3DV6) and one H-field sensor (H3DV6) [both from Schmid and Partner Engineering AG (SPEAG), Zurich, Switzerland], except for the medium and high power GSM chambers. These chambers were instrumented with two E-field probes because H-field probes saturated at high field strengths. This change in hardware did not result in the loss of monitoring capability. The measured E- and H-fields were communicated to the control computer in order to maintain exposure to selected levels of RFR. During daily shutdown periods when RFR exposures were not active, RF sensors monitored ambient RF fields in the exposure chambers. RF sensors were calibrated twice by the manufacturer (SPEAG); once prior to initiation of any of the animal studies and once prior to initiation of the 2-year studies. All E-field probes were calibrated in air from 100 MHz to 3.0 GHz, and had an absolute accuracy of ± 6.0% (k=2) with a spherical isotropy of better than ± 0.4 dB. All H-field probes were calibrated in air from 200 MHz to 3.0 GHz and had an absolute accuracy of ± 6.0% (k=2) with a spherical isotropy of better than ± 0.2 dB. Placement of probes within the chambers is discussed in the video[g] (day 1 a.m. at 1 hours, 31 minutes)[3].

Data collected by the RF sensors were transmitted to the exposure and monitoring system on a real-time basis and were recorded throughout the study. Chamber field strengths are reported as V/m and animal exposure levels (SAR values) are reported as W/kg. The chamber field strength is the average effective E-field strength from both probes. E-field and H-field strengths are related by the impedance of free space which is ~377 Ohms. Where an H-field probe was used, the value in A/m was multiplied by 377 to calculate the equivalent E-field strength in V/m; it is this effective E-field value that was used to report the chamber field strength. Field strength data reported for each day of exposure included mean ± standard deviation, minimum field strength, maximum field strength, total number of readings in range/total number of readings for the period, and percentage of readings in range. After each exposure day, RFR exposure data were downloaded onto DVDs for long-term archival. Summaries of the 2-year RFR exposure data from the studies are presented in Appendix I. The SAR and chamber-fields in the exposure chambers were within the target ranges (defined as ± 2 dB) for >99.85% of recorded measurements over the course of the 2-year study; ≥99.70% of recorded E-field and H-field measurements were within the target ranges for all but one chamber (97.35% within range). All recorded broadband field measurements (<40 MHz to >6 GHz) were below the limit of detection of the probes within the sham chamber showing that there was no significant confounding exposure. In the 28-day studies, the performance of the sham control and exposure chambers was similar for SAR and field measurements as in the 2-year studies (data not shown).

[g] https://doi.org/10.22427/NTP-VIDEO-41

As previously stated, the performance of the RFR exposure and monitoring system was independently validated by engineers from the NIST prior to the initiation of the animal studies.

Monitoring and Maintenance of Environmental Conditions

Environmental conditions including temperature, humidity, and airflow in all exposure chambers, as well as in other areas of the IITRI RFR exposure facility, were maintained by a computer-controlled environmental management system (Siemens Industries, Inc.). Monitoring instrumentation for each chamber was located in the air exhaust duct. Each chamber was fitted by the IT'IS Foundation with a sensor box that contained sensors for temperature and humidity (Type EE06; E + E Elektronik GmbH, Engerwitzdorf, Austria), oxygen level (Pewatron Type FCX-MC25; Zurich, Switzerland), air speed (model EE65A; E + E Elektronik GmbH), light (light-dependent resistor), noise (design based on WL-93 microphone; Shure Brothers, Inc., Evanston, IL), and RFR. Outputs from the sensor box were monitored using Agilent data acquisition units, with the exception of the RF sensor. The RF sensor was directly wired to a warning light as a safety precaution to indicate active RFR exposures and not intended to quantitatively measure RFR field strengths.

Exposure chambers were equipped with incandescent lights located on light bars in each corner of the chamber. All connections were RF-filtered. Chamber lighting was controlled using an adjustable daily cycle of 12 hours on, 12 hours off. In order to minimize the heat load generated by the incandescent lights, low wattage bulbs were used that maintained chamber lighting within a range that was sufficient to support normal in vivo operations, while minimally affecting chamber temperature. Further discussion of chamber lighting is found in the video[h] (day 1 a.m. at 1 hours, 27 minutes)[3].

Differences in noise levels in the exposure chambers resulting from the heating, ventilation, and air conditioning system were equalized by the installation of sound baffles in various ducts within the system. An audible signal generated by the high intensity GSM signal was detected and equalized in all chambers by the introduction of a "pink noise" masking sound; this masking noise equalized sound levels in all chambers. As a result of the combination of these efforts, noise levels in all chambers were essentially equivalent at approximately 62 dBA, and met the NC-35 noise specification. The noise criterion (NC) is a widely accepted numerical index commonly used to define the maximum allowable noise. It primarily applies to the noise produced by ventilation systems, but is applied to other noise sources, as well. Standards organizations, such as the American National Standards Institute (ANSI), Acoustical Society of America (ASA), and International Standards Organization, provide definitions of various NCs for ambient noise in enclosed spaces. The ANSI/ASA standard (S12.2-2008) recommends NCs for various types of rooms, including private residences (NC 25-40), schools (NC 25-35), offices (NC 25-40), libraries (NC 30-35), and restaurants (NC 40-45). For further discussion of noise control in these studies see the video[8] (day 1 a.m. at 2 hours, 0 minutes)[3].

[h] https://doi.org/10.22427/NTP-VIDEO-41

Animal Source

Male and female B6C3F1/N mice were obtained from the NTP colony maintained at Taconic Farms, Inc. (Germantown, NY), for the 28-day and 2-year studies.

Animal Welfare

Animal care and use are in accordance with the Public Health Service Policy on Humane Care and Use of Animals. All animal studies were conducted in an animal facility accredited by AAALAC International. Studies were approved by the IITRI Animal Care and Use Committee and conducted in accordance with all relevant NIH and NTP animal care and use policies and applicable federal, state, and local regulations and guidelines.

Twenty-eight-day Studies

The 28-day studies were conducted to evaluate the cumulative effects of repeated GSM- or CDMA-modulated cell phone RFR exposure and to determine the appropriate RFR power levels to be used in the 2-year studies. The exposure levels in these studies were selected based on the findings of minimal increases in body temperature observed in 5-day studies at exposures up to 12 W/kg RFR[144].

Groups of 10 male and 10 female mice were housed in reverberation chambers and received whole-body exposures to GSM- or CDMA-modulated cell phone RFR at power levels of 0 (sham control), 5, 10, or 15 W/kg, for 9 hours and 10 minutes per day for 5 or 7 (last week of study) days per week for at least 28 days with continuous cycling of 10 minutes on and 10 minutes off during a period of 18 hours and 20 minutes each day. The sham control animals were housed in a reverberation chamber identical to those used for the exposed groups, but they were not exposed to RFR; a shared group of unexposed mice of each sex served as sham controls for both RFR modulations.

Animals were observed twice daily and were weighed once during quarantine, initially, and weekly thereafter. Clinical signs were recorded once during quarantine and then weekly. In core study mice, subcutaneously implanted temperature microchips and monitoring equipment (Bio Medic Data Systems, Seaford, DE) were used to monitor individual animal body temperatures. Body temperature measurements were taken prior to initial exposure at the beginning of the study, on days 7 and 14 during inactive shutdown periods with no exposure, and on days 2, 4, 17, 20, and 27 within 5 minutes of exposure pauses at the end of the second to the last “on” cycle at the same time each day.

Mice were quarantined for 9 or 3 days (first and second shipment, respectively) before the beginning of the studies. Ten mice (two males and eight females) that were not assigned during randomization were selected for parasite evaluation and gross observation of disease. Mice were approximately 5 to 6 weeks old at the beginning of the studies. The health of the animals was monitored during the studies according to the protocols of the NTP Sentinel Animal Program (Appendix K). All test results were negative.

Mice were housed individually. Feed and water were available *ad libitum*. To avoid interference with RFR dosimetry, feed was provided in ceramic (nonmetallic) bowls and water was delivered in an adapted automatic watering system[146]. Cages were changed weekly and rotated within the

racks weekly; racks were changed biweekly. Further details of animal maintenance are given in Table 1. Information on feed composition and contaminants is provided in Appendix J.

Necropsies were performed on all core study mice on day 29 or 30. Organs weighed were the right adrenal gland, brain, heart, right kidney, liver, lung, right testis, and thymus. Tissues for microscopic examination were fixed and preserved in 10% neutral buffered formalin (except eyes, testis with epididymis, and vaginal tunics were first fixed in Davidson's solution or modified Davidson's solution), processed and trimmed, embedded in paraffin, sectioned to a thickness of 4 to 6 µm, and stained with hematoxylin and eosin. Complete histopathologic examinations were performed by the study laboratory pathologist on all 0 (sham control) and 15 W/kg GSM- and 15 W/kg CDMA-modulated cell phone RFR core study mice. Table 1 lists the tissues and organs routinely examined.

After a review of the laboratory reports and selected histopathology slides by a quality assessment (QA) pathologist (QAP), the findings and differences of opinions between the study pathologist (SP) and the QAP were reviewed by the NTP pathologist. Slides containing representative lesions of exposure-related lesions or differences of opinions between pathologists were brought to a Pathology Peer Review (PPR). A pathology peer review typically consists of a small group (three to eight) of pathologists who examine the lesions around a multiheaded microscope. It is frequently used to review lesions in short term studies, issues of terminology, or examine single issues that have arisen during a pathology working group (PWG – see below). Final diagnoses for reviewed lesions represent a consensus of the PPR or a consensus between the study laboratory pathologist, NTP pathologist, and the QAP(s). Details of these review procedures have been described, in part, by Maronpot and Boorman[147] and Boorman et al.[148].

A further discussion of pathology review procedures is found in the video[i] (day 2 a.m. at 1 hours, 0 minutes)[3].

Two-year Studies

Study Design

Groups of 105 male and 105 female mice were housed in reverberation chambers and received whole-body exposures to GSM- or CDMA-modulated cell phone RFR at power levels of 0 (sham control), 2.5, 5, or 10 W/kg, 9 hours and 10 minutes per day, 7 days per week for 106 (males) or 108 (females) weeks with continuous cycling of 10 minutes on and 10 minutes off during a period of 18 hours and 20 minutes each day. The sham control animals were housed in reverberation chambers identical to those used for the exposed groups, but were not exposed to RFR; shared groups of unexposed mice of each sex served as sham controls for both RFR modulations. Fifteen mice per group were randomly selected from the core group after 10 weeks of study; ten mice per group were randomly selected for interim evaluation at 14 weeks, and five mice per group were used for genetic toxicity testing at 14 weeks.

Mice were quarantined for 9 days before the beginning of the studies. An additional five male and five female mice not assigned during randomization were selected for parasite evaluation and gross observation of disease. Mice were approximately 5 to 6 weeks old at the beginning of

[i] https://doi.org/10.22427/NTP-VIDEO-43

the studies. The health of the animals was monitored during the studies according to the protocols of the NTP Sentinel Animal Program (Appendix K). All test results were negative.

Mice were housed individually. Feed and water were available *ad libitum*. To avoid interference with RFR dosimetry, feed was provided in ceramic (nonmetallic) bowls and water was delivered in an adapted automatic watering system (see video[j], day 1 a.m. at 2 hours, 5 minutes)[3; 146]. Cages were changed weekly and rotated within the racks biweekly; racks were changed biweekly. Further details of animal maintenance are given in Table 1. Information on feed composition and contaminants is provided in Appendix J.

Clinical Examinations and Pathology

Animals were observed twice daily and were weighed initially, weekly for the first 14 weeks, at 4-week intervals during weeks 14 to 86, and then every 2 weeks from week 90 until the end of the studies. Clinical signs were recorded once during quarantine and at least every 4 weeks during the studies.

Hematology evaluations were performed on 10 male and 10 female interim evaluation mice from each group at 14 weeks. Mice were anesthetized with 70% CO_2/30% O_2 and blood was collected from the retroorbital sinus and placed into tubes containing EDTA as an anticoagulant. Hematology parameters were determined on an ADVIA™ 120 automated hematology analyzer (Bayer Diagnostic Division, Tarrytown, NY). The parameters measured are listed in Table 1. Wright Giemsa stained peripheral blood smears were prepared and evaluated for any blood cell abnormalities. Blood was collected from the remaining five male and five female interim evaluation mice per exposure group at 14 weeks for use in the comet and micronucleus assays; methods for these assays are presented in Appendix E.

At 14 weeks, samples were collected for sperm motility and count and vaginal cytology evaluations on 10 male and 10 female interim evaluation mice from each group. The parameters evaluated are listed in Table 1. For 15 or 16 consecutive days prior to scheduled euthanasia, the vaginal vaults of the females were moistened with saline, if necessary, and samples of vaginal fluid and cells were stained. Relative numbers of leukocytes, nucleated epithelial cells, and large squamous epithelial cells were determined and used to ascertain estrous cycle stage (i.e., diestrus, proestrus, estrus, and metestrus). Male animals were evaluated for sperm count and motility. The left testis and left epididymis were isolated and weighed. The tail of the epididymis (cauda epididymis) was then removed from the epididymal body (corpus epididymis) and weighed. Modified Tyrode's buffer was applied to slides and a small incision was made at the distal border of the cauda epididymis. The sperm effluxing from the incision were dispersed in the buffer on the slides, and the numbers of motile and nonmotile spermatozoa were counted for five fields per slide by two observers. Following completion of sperm motility estimates, each left cauda epididymis was placed in buffered saline solution. Caudae were finely minced, and the tissue was incubated in the saline solution and then heat fixed at 65°C. Sperm density was then determined microscopically with the aid of a hemacytometer. To quantify spermatogenesis, the testicular spermatid head count was determined by removing the tunica albuginea and

[j] https://doi.org/10.22427/NTP-VIDEO-41

homogenizing the left testis in phosphate-buffered saline containing 10% dimethyl sulfoxide. Homogenization-resistant spermatid nuclei were counted with a hemacytometer.

All mice were necropsied. The cerebrum, frontal cortex, hippocampus, and liver were collected from five male and five female interim sacrifice animals per exposure group at 14 weeks for use in the comet assay; methods for this assay are presented in Appendix E. Microscopic examinations were performed on 10 male and 10 female interim evaluation mice in each group at 14 weeks and all core study mice, including those found dead or euthanized moribund. At the interim evaluation, the brain, right and left epididymides, heart, right and left kidneys, liver, lung, right and left ovaries, right and left testes, and thymus were weighed. At necropsy, all organs and tissues were examined for grossly visible lesions, and all major tissues were fixed and preserved in 10% neutral buffered formalin (except eyes were first fixed in Davidson's solution, and testes, vaginal tunics, and epididymides were first fixed in modified Davidson's solution), processed and trimmed, embedded in paraffin, sectioned to a thickness of 4 to 6 µm, and stained with hematoxylin and eosin for microscopic examination. For all paired organs (e.g., adrenal gland, kidney, ovary), samples from each organ were examined. Tissues examined microscopically are listed in Table 1.

Microscopic evaluations were completed by the study laboratory pathologist, and the pathology data were entered into the Toxicology Data Management System. The report, slides, paraffin blocks, residual wet tissues, and pathology data were sent to the NTP Archives for inventory and NTP PPR. All data and materials are available for review upon request from the NTP Archives.

NTP Pathology Review Process

Typically, the initial reading of the slides and the first steps of the pathology review are done by an open, or non-blinded, evaluation by the pathologists involved. This is standard practice for NTP, as well as the toxicologic pathology industry as a whole, and is in accordance with the recommendations of the Society of Toxicologic Pathologists[149-154]. If issues arise where subtle lesions need to be identified or graded by a blinded evaluation, the pathologist will perform this.

The primary goals of the NTP pathology review are to reach consensus agreement on the diagnosis of all potentially treatment-related findings, confirm the diagnoses of all neoplasms, confirm that consistent and acceptable nomenclature is being used, and confirm the diagnosis of any unusual lesions. There are several elements in this process:

Pathology Data Review (PDR) is a complete review of the pathology data generated by the study laboratory to identify potential target organs and discrepant data and to harmonize terminology. The review involves a multidisciplinary meeting by the NTP staff and pathology support-contract pathologists to determine the organs and lesions to be reviewed by the quality assessment pathologist (QAP), including all neoplasms.

Audit of Pathology Specimens (APS) is a review of the physical data and residual wet tissues (typically from 10% of the animals) to ensure all gross lesions were evaluated microscopically; of the slides and blocks (typically from 10% of the animals) to ensure correct labeling and quality of sections; and of the submitted reports to ensure accuracy. Also evaluated is whether or not the study laboratory adhered to NTP pathology specifications.

Quality Assessment is a review of the slides of target organs and lesions identified in the PDR by a pathologist from one of NTP's pathology support contract laboratories not involved with the initial pathology evaluation of the study. For the 2-year mouse RFR studies, a QA pathologist evaluated slides from all tumors and all potential target organs, which included the brain, spinal cord, heart, and kidney. In addition, the liver, large intestine (cecum and colon), small intestine (duodenum, jejunum, and ileum), lung, testis, urinary bladder, and Harderian gland were reviewed from all male mice for specific lesions; and the bronchial and mesenteric lymph nodes, spleen, ovary, urinary bladder, Harderian gland, and thyroid gland were reviewed from all female mice for specific lesions. All differences in diagnoses between the study pathologist (SP) and QAP are identified in the Differences Report prepared by the QAP. The NTP pathologist attempts to resolve the discrepant diagnoses between the SP and QAP; those that are not resolved are reviewed by the pathology working group (PWG).

Pathology Working Group is a review of selected slides by a panel of pathologists in order to confirm the diagnoses of all treatment-related neoplastic and nonneoplastic lesions and unusual lesions, resolve discrepancies between the SP, QAP, and NTP pathologist, harmonize nomenclature, propose further characterization of the lesions, and address possible mechanisms. The QAP, with oversight from the NTP pathologist, selects slides for the PWG and conducts the PWG. Typically, experts in a particular organ of interest are invited to participate.

A *Pathology Peer Review* (PPR) is a peer review meeting that convenes to resolve minor issues or issues limited in scope (such as review of short-term studies with limited findings), or review findings of post-PWG actions. Reports are prepared for all these activities. Final diagnoses for reviewed lesions represent a consensus between the laboratory pathologist, QA pathologist(s), and the PWG.

Once the PWG and/or PPR is complete, all written documentation of data changes is reviewed for accuracy and the study data are updated. The pathology data and all written documentation of data changes are then submitted to an outside independent auditor to ensure the accuracy of the updated data. Once all issues identified by the independent auditor have been addressed, the final pathology data tables are generated. For subsequent analyses of the pathology data, the decision of whether to evaluate the diagnosed lesions for each tissue type separately or combined was generally based on the guidelines of Brix et al.[155].

Table 1. Experimental Design and Materials and Methods in the Whole-Body Exposure Studies of GSM- and CDMA-modulated Cell Phone RFR

Twenty-eight-day Studies	Two-year Studies
Study Laboratory	
IIT Research Institute (Chicago, IL)	Same as 28-day studies
Strain and Species	
B6C3F1/N mice	Same as 28-day studies
Animal Source	
Taconic Farms, Inc. (Germantown, NY)	Same as 28-day studies
Time Held Before Studies	
9 and 3 days (first and second shipment, respectively)	9 days
Average Age When Studies Began	
Approximately 5 to 6 weeks	5 to 6 weeks
Date of First Exposure	
September 6, 2010	June 18, 2012
Duration of Exposure	
9 hours and 10 minutes per day, 7 days per week, over the course of 18 hours and 20 minutes, in 10-minute-on, 10-minute-off intervals for 28 days.	9 hours and 10 minutes per day, 7 days per week, over the course of 18 hours and 20 minutes, in 10-minute-on, 10-minute-off intervals for 14 weeks (interim evaluation) or 106 (males) or 108 (females) weeks (2-year studies).
Date of Last Exposure	
October 3 or 4, 2010	Males: June 26, 2014 Females: July 9, 2014
Necropsy Dates	
October 4 or 5, 2010	Males: June 16 to 26, 2014 Females: June 26 to July 9, 2014
Age at Necropsy	
Approximately 9 to 10 weeks	Males: 110 to 112 weeks Females: 111 to 114 weeks
Size of Study Groups	
10 males and 10 females	Core study: 90 males and 90 females Interim evaluation: 10 male and 10 females Genetic toxicity: Five male and five females
Method of Distribution	
Animals were distributed randomly into groups of approximately equal initial mean body weights.	Same as 28-day studies
Animals per Cage	
1	Same as 28-day studies
Method of Animal Identification	
Tail tattoo	Same as 28-day studies

Twenty-eight-day Studies	Two-year Studies
Diet	
Certified, irradiated NTP-2000 rodent diet wafer (Zeigler Brothers, Inc., Gardners, PA), available ad libitum, ceramic feed bowls changed weekly	Same as 28-day studies
Water	
Tap water (Chicago municipal supply) via an adapted automatic watering system (SE Lab Group, Cincinnati, OH), available ad libitum	Same as 28-day studies
Cages	
Polycarbonate, solid bottom “shoebox” cages (Allentown Caging, Allentown, NJ), changed and rotated within the rack weekly	Same as 28-day studies, except changed weekly and rotated within the rack biweekly
Bedding	
Certified, irradiated hardwood bedding (P.J. Murphy Forest Products Corp., Montville, NJ), changed weekly	Same as 28-day studies
Racks	
Custom-designed fiberglass cage racks (Ultra, Inc., Milwaukee, WI), changed biweekly	Same as 28-day studies
Reverberation Chambers	
Fully-shielded, stainless steel room equipped with a stainless steel door to eliminate leakage of RFR signals, RFR excitation antennas, and two rotating stirrers; chambers were cleaned at least once weekly.	Same as 28-day studies
Reverberation Chamber Environment	
Temperature: 72° ± 3° F Relative humidity: 50% ± 15% Room incandescent light: 12 hours/day Chamber air changes: at least 10/hour	Same as 28-day studies
Exposure Concentrations	
Time-averaged whole-body SARs of 0 (sham control), 5, 10, and 15 W/kg GSM- or CDMA-modulated cell phone RFR	Time-averaged whole-body SARs of 0 (sham control), 2.5, 5, and 10 W/kg GSM- or CDMA-modulated cell phone RFR
Type and Frequency of Observation	
Observed twice daily; animals were weighed once during quarantine, initially, and weekly thereafter. Clinical signs were recorded once during quarantine and then weekly. Body temperature measurements were taken on core study mice prior to initial exposure at the beginning of the study, on days 7 and 14 during inactive exposures, and on days 2, 4, 17, 20, and 27 within 5 minutes of exposure pauses at the end of the second to the last “on” cycle.	Observed twice daily; animals were weighed initially, weekly for the first 14 weeks, at 4-week intervals during weeks 14 to 86, and then every 2 weeks from week 90 until the end of the studies. Clinical signs were recorded once during quarantine and at least once every 4 weeks during the studies.

Twenty-eight-day Studies	Two-year Studies
Method of Euthanasia	
Carbon dioxide asphyxiation	Same as 28-day studies
Necropsy	
Necropsies were performed on all core study mice on day 29 or 30. Organs weighed were the right adrenal gland, brain, heart, right kidney, liver, lung, right testis, and thymus.	Necropsies were performed on all mice. Organs weighed in 10 mice per exposure group at 14 weeks were the brain, heart, kidneys (right and left), liver, lung, ovaries (right and left), testes (right and left) with epididymides (right and left), and thymus.
Clinical Pathology	
None	Blood was collected from the retroorbital sinus of 10 mice per group at 14 weeks for hematology. ***Hematology***: hematocrit (auto and manual); hemoglobin concentration; erythrocyte, reticulocyte, and platelet counts; erythrocyte, leukocyte, and platelet morphology; mean cell volume; mean cell hemoglobin; mean cell hemoglobin concentration; and leukocyte count and differentials
Histopathology	
Complete histopathology was performed on all 0 (sham control) and 15 W/kg groups. In addition to gross lesions and tissue masses, the following tissues were examined: adrenal gland, aorta, bone with marrow, brain, clitoral gland, esophagus, eyes, gallbladder, Harderian gland, heart, large intestine (cecum, colon, rectum), small intestine (duodenum, jejunum, ileum), kidney, liver, lung, lymph nodes (mandibular and mesenteric), mammary gland, muscle, nerve (sciatic), nose, oral cavity, ovary, pancreas, pituitary gland, preputial gland, prostate gland, salivary gland, seminal vesicle, skin, spinal cord, spleen, stomach (forestomach and glandular), testis with epididymis, thymus, thyroid gland, tongue, trachea, urinary bladder, and uterus.	Complete histopathology was performed on 10 mice from each group at 14 weeks, on all mice that died early, and on all mice surviving to the end of the studies. In addition to gross lesions and tissue masses, the following tissues were examined: adrenal gland, aorta, bone with marrow, brain, clitoral gland, esophagus, eyes, gallbladder, Harderian gland, heart, large intestine (cecum, colon, rectum), small intestine (duodenum, jejunum, ileum), kidney, liver, lung with bronchi, lymph nodes (mandibular and mesenteric), mammary gland, muscle, nerve (sciatic, trigeminal, and ganglion), nose, ovary, pancreas, pituitary gland, preputial gland, prostate gland, salivary gland, seminal vesicle, skin, spinal cord, spleen, stomach (forestomach and glandular), testis with epididymis, thymus, thyroid gland, trachea, urinary bladder, and uterus.
Sperm Motility and Count and Vaginal Cytology	
None	Spermatid and sperm samples were collected from 10 male mice in each group at 14 weeks. The following parameters were evaluated: spermatid heads per testis and per gram testis, sperm motility, and sperm per cauda epididymis and per gram cauda epididymis. The left cauda, left epididymis, and left testis were weighed. Vaginal samples were collected from 10 females in each group for 15 or 16 days prior to the 14-week interim evaluation.

Statistical Methods

For all analyses, P values less than 0.05 were considered statistically significant. Statistical significance is one component of the "weight of evidence" approach to evaluate carcinogenicity (described in Explanation of Levels of Evidence of Carcinogenic Activity).

Survival Analyses

The probability of survival was estimated by the product-limit procedure of Kaplan and Meier[156] and is presented in the form of graphs. Animals found dead of other than natural causes or missing were censored; animals dying from natural causes were not censored. Statistical analyses for possible dose-related effects on survival used Cox's[157] method for testing two groups for equality and Tarone's[158] life table test to identify dose-related trends. All reported P values for the survival analyses are two sided.

Calculation of Incidence

The incidences of neoplasms or nonneoplastic lesions are presented in Table A-1, Table A-5, Table B-1, Table B-4, Table C-1, Table C-4, Table D-1, and Table D-4 as the numbers of animals bearing such lesions at a specific anatomic site and the numbers of animals with that site examined microscopically. For calculation of statistical significance, the incidences of most neoplasms (Table A-2, Table B-2, Table C-2, Table D-2) and all nonneoplastic lesions are given as the numbers of animals affected at each site examined microscopically. However, when macroscopic examination was required to detect neoplasms in certain tissues (e.g., mesentery, pleura, peripheral nerve, skeletal muscle, tongue, tooth, and Zymbal's gland) before microscopic evaluation, the denominators consist of the number of animals that had a gross abnormality. When neoplasms had multiple potential sites of occurrence (e.g., leukemia or lymphoma), the denominators consist of the number of animals on which a necropsy was performed. Table A-2, Table B-2, Table C-2, and Table D-2 also give the survival-adjusted neoplasm rate for each group and each site-specific neoplasm. This survival-adjusted rate (based on the Poly-3 method described below) accounts for differential mortality by assigning a reduced risk of neoplasm, proportional to the third power of the fraction of time on study, only to site-specific, lesion-free animals that do not reach terminal euthanasia.

Analysis of Neoplasm and Nonneoplastic Lesion Incidences

The Poly-k test[159-161] was used to assess neoplasm and nonneoplastic lesion prevalence. This test is a survival-adjusted quantal-response procedure that modifies the Cochran-Armitage linear trend test to take survival differences into account. More specifically, this method modifies the denominator in the quantal estimate of lesion incidence to approximate more closely the total number of animal years at risk. For analysis of a given site, each animal is assigned a risk weight. This value is one if the animal had a lesion at that site or if it survived until terminal euthanasia; if the animal died prior to terminal euthanasia and did not have a lesion at that site, its risk weight is the fraction of the entire study time that it survived, raised to the kth power.

This method yields a lesion prevalence rate that depends only upon the choice of a shape parameter for a Weibull hazard function describing cumulative lesion incidence over time[159]. Unless otherwise specified, a value of k = 3 was used in the analysis of site-specific lesions. This value was recommended by Bailer and Portier[159] following an evaluation of neoplasm onset time

distributions for a variety of site-specific neoplasms in control F344 rats and B6C3F1 mice[162]. Bailer and Portier[159] showed that the Poly-3 test gave valid results if the true value of k was anywhere in the range from 1 to 5. A further advantage of the Poly-3 method is that it does not require lesion lethality assumptions. Variation introduced by the use of risk weights, which reflect differential mortality, was accommodated by adjusting the variance of the Poly-3 statistic as recommended by Bieler and Williams[163].

Tests of significance included pairwise comparisons of each dosed group with controls and a test for an overall dose-related trend. Continuity-corrected Poly-3 tests were used in the analysis of lesion incidence, and reported P values are one sided. The significance of lower incidences or decreasing trends in lesions is represented as 1–P with the letter N added (e.g., P = 0.99 is presented as P = 0.01N). For neoplasms and nonneoplastic lesions detected at the interim evaluation, the Fisher exact test[164], a procedure based on the overall proportion of affected animals, was used.

Analysis of Continuous Variables

Two approaches were employed to assess the significance of pairwise comparisons between dosed and control groups in the analysis of continuous variables. Organ and body weight data, which historically have approximately normal distributions and body temperatures, were analyzed with the parametric multiple comparison procedures of Dunnett[165] and Williams[166; 167]. Hematology, spermatid, and epididymal spermatozoal data, which have typically skewed distributions, were analyzed using the nonparametric multiple comparison methods of Shirley[168] (as modified by Williams[169]) and Dunn[170]. Jonckheere's test[171] was used to assess the significance of the dose-related trends and to determine whether a trend-sensitive test (Williams' or Shirley's test) was more appropriate for pairwise comparisons than a test that does not assume a monotonic dose-related trend (Dunnett's or Dunn's test). Prior to statistical analysis, extreme values identified by the outlier test of Dixon and Massey[172] were examined by NTP personnel, and implausible values were eliminated from the analysis. Tests for extended periods of estrus, diestrus, metestrus, and proestrus, as well as skipped estrus and skipped diestrus, were constructed based on a Markov chain model proposed by Girard and Sager[173]. For each dose group, a transition probability matrix was estimated for transitions among the proestrus, estrus, metestrus, and diestrus stages, with provision for extended stays within each stage as well as for skipping estrus or diestrus within a cycle. Equality of transition matrices among dose groups and between the control group and each dosed group was tested using chi-square statistics. P values for these analyses are two-sided.

Historical Control Data

The concurrent control group represents the most valid comparison to the treated groups and is the only control group analyzed statistically in NTP bioassays. However, historical control data are often helpful in interpreting potential treatment-related effects, particularly for uncommon or rare neoplasm types. For meaningful comparisons, the conditions for studies in the historical control database must be generally similar. Significant factors affecting the background incidences of neoplasms at a variety of sites are diet, sex, strain/stock, and route of exposure. The NTP historical control database contains all 2-year studies for each species, sex, and strain/stock with histopathology findings in control animals completed within the most recent 5-year period[174-176]. In general, the historical control database for a given study includes studies using

the same route of administration, and the overall incidences of neoplasms in controls for all routes of administration are included for comparison. Because the two mouse studies presented in this report are the only two using this whole-body exposure method, only the overall incidences for all routes are included. A list of the specific NTP studies included in this database and a summary of the historical control data for the lesions of interest are presented in the Appendices (Table A-3, Table B-3, Table C-3, Table D-3).

Quality Assurance Methods

The 28-day and 2-year studies were conducted in compliance with Food and Drug Administration Good Laboratory Practice Regulations[177]. In addition, the 28-day and 2-year study reports were audited retrospectively by an independent QA contractor against study records submitted to the NTP Archives. Separate audits covered completeness and accuracy of the pathology data, pathology specimens, final pathology tables, and a draft of this NTP Technical Report. Audit procedures and findings are presented in the reports and are on file at NIEHS. The audit findings were reviewed and assessed by NTP staff, and all comments were resolved or otherwise addressed during the preparation of this Technical Report.

Genetic Toxicology

The genetic toxicity of GSM- and CDMA-modulated RFR was assessed by measuring the frequency of micronucleated erythrocytes in peripheral blood and DNA damage in five different tissues of male and female mice following 14 weeks of exposure. Micronuclei (literally “small nuclei” or Howell-Jolly bodies) are biomarkers of induced structural or numerical chromosomal alterations and are formed when acentric fragments or whole chromosomes fail to incorporate into either of two daughter nuclei during cell division[178; 179]. The alkaline (pH>13) comet assay[180] (also known as the single cell gel electrophoresis assay) detects DNA damage in any of a variety of eukaryotic cell types[181-184]; cell division is not required. The type of DNA damage detected includes nicks, adducts, strand breaks, and abasic sites that are converted to DNA strand breaks after treatment of cells in an alkaline (pH>13) solution. Transient DNA strand breaks generated by the process of DNA excision repair may also be detected. DNA damage caused by crosslinking agents has been detected as a reduction of DNA migration[185; 186]. The fate of the DNA damage detected by the comet assay is varied; most of the damage is rapidly repaired resulting in no sustained impact on the tissue but some may result in cell death or may be incorrectly processed by the repair proteins and result in a fixed mutation or chromosomal alteration. The detailed protocols for these studies and the results are given in Appendix E.

The genetic toxicity studies have grown out of an earlier effort by NTP to develop a comprehensive database permitting a critical anticipation of a test article’s carcinogenicity in experimental animals based on the results from a number of in vitro and in vivo short-term tests measuring functionally distinct genotoxicity endpoints. The short-term tests were originally developed to clarify proposed mechanisms of chemical-induced DNA damage based on the relationship between electrophilicity and mutagenicity[187] and the somatic mutation theory of cancer[188; 189]. However, it should be noted that not all cancers arise through genotoxic mechanisms, and in these studies, the test article is not a chemical. Many studies have established the genotoxicity of some forms of radiation including, for example, ultraviolet radiation and X-ray radiation, which are both forms of ionizing radiation. Because exposure to

RFR requires specialized and highly technical exposure protocols, only in vivo biomarkers associated with genotoxicity could be investigated.

Clearly positive results in long-term peripheral blood micronucleus tests have high predictivity for rodent carcinogenicity; a weak response in one sex only or negative results in both sexes in this assay do not correlate well with either negative or positive results in rodent carcinogenicity studies[190]. The relationship between comet assay results and rodent carcinogenicity was investigated previously and a close association was observed[191]; however, this assay is best employed as a hazard identification assay. Because of the theoretical and observed associations between induced genetic damage and adverse effects in somatic and germ cells, the determination of in vivo genetic effects is important to the overall understanding of the risks associated with exposure to a particular test article.

Further discussion of the genetic toxicology assays used in these studies can be found in the video[k] (day 2 a.m. at 2 hours, 48 minutes)[3].

[k] https://doi.org/10.22427/NTP-VIDEO-43

Results

Data Availability

The National Toxicology Program (NTP) evaluated all study data. Data relevant for evaluating toxicological findings are presented here. All study data are available in the NTP Chemical Effects in Biological Systems (CEBS) database: https://doi.org/10.22427/NTP-DATA-TR-596.

GSM

Twenty-eight-day Study

All mice survived to the end of the study (Table 2). Weekly mean body weights of exposed groups of males and females were similar to those of the sham controls at all time points (Table 2; Figure 6). There were no clinical signs related to exposure to GSM-modulated RFR.

Body temperatures were significantly higher in RFR-exposed male mice at several time points (Table 3). In female mice, there were a few occurrences of significantly lower body temperatures in the exposed groups, but no significantly higher body temperatures. These changes in body temperature were inconsistent and not SAR-related.

Table 2. Mean Body Weights and Survival of Mice Exposed to GSM-modulated Cell Phone RFR for 28 Days

	Sham Control		5 W/kg			10 W/kg			15 W/kg		
Day	Av. Wt. (g)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors
Male											
1	20.2	10	20.0	98.9	10	20.4	100.8	10	21.1	104.7	10
8	21.8	10	22.2	101.5	10	21.8	99.8	10	22.6	103.3	10
15	22.8	10	23.1	101.4	10	22.7	99.4	10	23.2	101.7	10
22	24.0	10	24.2	101.0	10	23.8	99.4	10	24.1	100.5	10
29	24.9	10	25.2	101.2	10	24.7	99.5	10	25.0	100.5	10
Female											
1	18.1	10	17.8	98.3	10	17.4	96.1	10	17.9	98.9	10
8	18.9	10	19.0	100.7	10	18.4	97.3	10	18.5	98.0	10
15	20.1	10	20.1	100.0	10	19.5	97.0	10	19.6	97.3	10
22	21.0	10	21.1	100.4	10	20.4	97.1	10	20.3	96.8	10
30	21.7	10	21.9	100.9	10	21.2	97.5	10	21.0	96.6	10

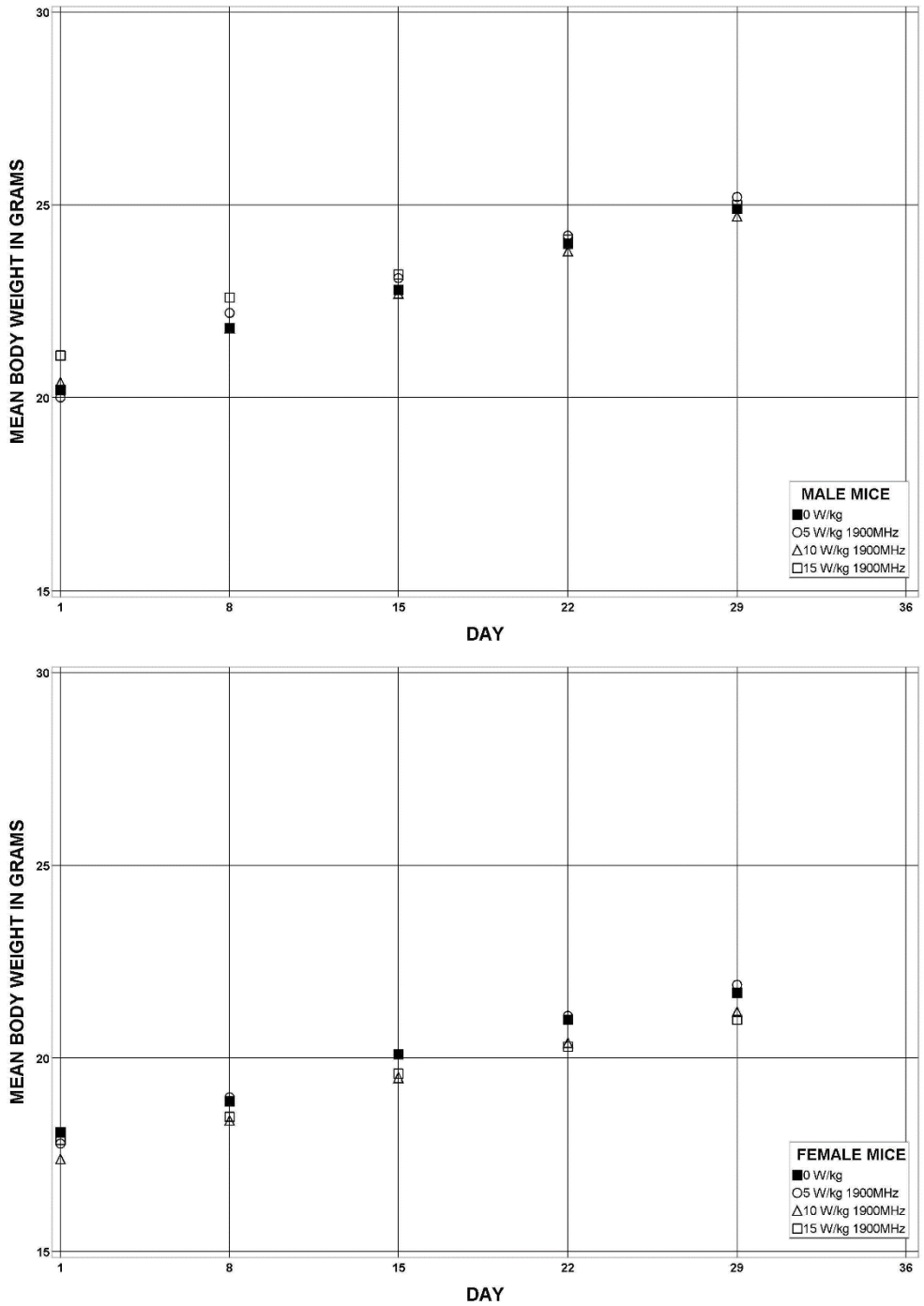

Figure 6. Growth Curves for Mice Exposed to GSM-modulated Cell Phone RFR for 28 Days

Table 3. Mean Body Temperatures of Mice Exposed to GSM-modulated Cell Phone RFR for 28 Days[a]

	Sham Control		5 W/kg		10 W/kg		15 W/kg	
Day	Temperature (°C)	No. Measured	Temperature (°C)	No. Measured	Temperature (°C)	No. Measured	Temperature (°C)	No. Measured
Male								
0	37.0 ± 0.2	10	38.5 ± 0.2	10	37.3 ± 0.3	10	36.2 ± 0.2*	10
2	35.7 ± 0.1	10	37.2 ± 0.3**	10	37.1 ± 0.3**	10	37.0 ± 0.3**	10
4	36.2 ± 0.2	10	37.0 ± 0.2	10	37.1 ± 0.3*	10	37.1 ± 0.2*	10
7[b]	36.6 ± 0.2	9	37.4 ± 0.2	10	37.7 ± 0.4*	10	36.8 ± 0.1	10
14[b]	35.5 ± 0.3	10	36.0 ± 0.1	10	36.1 ± 0.4	10	35.9 ± 0.1	10
17	36.0 ± 0.3	10	37.2 ± 0.3*	10	36.7 ± 0.3	10	36.8 ± 0.4	10
20	36.5 ± 0.3	10	37.0 ± 0.3	10	37.6 ± 0.3*	10	37.2 ± 0.2	10
27	35.8 ± 0.4	9	37.6 ± 0.3**	10	37.4 ± 0.2**	10	37.2 ± 0.3**	10
2–27[c]	36.0 ± 0.2	10	37.1 ± 0.1**	10	37.1 ± 0.2**	10	36.9 ± 0.2**	10
Female								
0	38.1 ± 0.1	10	37.9 ± 0.1	9	37.2 ± 0.3**	9	37.2 ± 0.1**	10
2	37.5 ± 0.2	10	37.4 ± 0.2	9	37.3 ± 0.3	9	37.5 ± 0.1	10
4	37.0 ± 0.2	10	37.5 ± 0.2	10	37.1 ± 0.5	10	37.6 ± 0.1	10
7[b]	38.6 ± 0.1	10	38.1 ± 0.2	10	37.8 ± 0.5	10	38.5 ± 0.1	10
14[b]	36.9 ± 0.1	10	36.4 ± 0.1	10	36.6 ± 0.2	9	37.0 ± 0.2	10
17	37.9 ± 0.1	10	37.3 ± 0.2**	10	37.7 ± 0.1	9	37.6 ± 0.1	10
20	37.7 ± 0.2	10	37.6 ± 0.2	10	37.6 ± 0.1	9	37.8 ± 0.1	10
27	37.8 ± 0.1	10	38.2 ± 0.1	10	37.2 ± 0.2*	9	37.5 ± 0.2	10
2–27[c]	37.6 ± 0.1	10	37.5 ± 0.1	10	37.3 ± 0.2	10	37.6 ± 0.1	10

*Significantly different ($P \leq 0.05$) from the sham control group by Williams' or Dunnett's test.
**$P \leq 0.01$.
[a]Temperatures are given as mean ± standard error.
[b]All temperatures were recorded within 5 minutes of the exposure cessation, except for the measurements on days 7 and 14, which were recorded at least 1 hour after exposure.
[c]Average of days 2 to 27, excluding days 7 and 14.

There were no exposure-related effects on the organ weights of males exposed to GSM-modulated RFR (Table G-1). The absolute heart weight of 15 W/kg females was significantly less than that of the sham controls, and there were negative trends in the absolute weights of the brain, right kidney, and liver, all of which were considered to be due to minor reductions in body weight. There were no significantly lower relative organ weights and no associated histopathologic findings, therefore, these organ weight changes were considered sporadic and not related to GSM-modulated RFR exposure.

There were no histopathologic lesions related to the effects of exposure to GSM-modulated RFR.

Exposure Level Selection Rationale: In male and female mice exposed for 5 days to RFR up to 12 W/kg, only sporadic increases were observed in body temperature, regardless of the sex or

age of the animals[144]. Because no significant effects of RFR were observed in body temperature at 12 W/kg, a higher upper exposure level was selected for the 28-day studies. Due to limits on the maximum capacity of the exposure system to generate high RF fields, the maximum achievable exposure level capacity was 15 W/kg, which was selected as the highest exposure level for the 28-day studies. Selection of the highest exposure level for the 2-year studies was also limited by the power capacity of the exposure system to generate maximum RF fields. Based on these limitations and increased body temperature at various time points that were similarly observed at 10 and 15 W/kg in the 28-day studies, the exposure levels selected for the 2-year studies were 2.5, 5, and 10 W/kg.

Two-year Study

Survival

Estimates of 2-year survival probabilities for male and female mice are shown in Table 4 and in the Kaplan-Meier survival curves (Figure 7). Survival was significantly higher for the 5 W/kg males than the sham control group. Survival of the rest of the exposed groups of males and females was generally similar to that of the sham controls.

Body Weights and Clinical Observations

Mean body weights of exposed groups of males and females were similar to those of the sham controls throughout the study (Table 5, Table 6; Figure 8). Clinical signs included more occurrences of thin and ruffled fur in 10 W/kg males and thin, ruffled fur, and mass-torso/ventral in 5 and 10 W/kg females. These findings were not correlated with differences in body weights or incidences of neoplasms in exposed animals.

Table 4. Survival of Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Male				
Animals initially in study	105	105	105	105
14-week interim evaluation[a]	15	15	15	15
Accidental death[b]	0	1	0	0
Missing[b]	0	1	0	0
Moribund	8	6	2	6
Natural deaths	16	19	8	12
Animals surviving to study termination	66	63	80[f]	72[g]
Percent probability of survival at end of study[c]	73	72	89	80
Mean survival (days)[d]	687	693	717	707
Survival analysis[e]	P = 0.135N	P = 0.959	P = 0.013N	P = 0.360N
Female				
Animals initially in study	105	105	105	105
14-week interim evaluation[a]	15	15	15	15
Moribund	9	9	9	6

	Sham Control	**2.5 W/kg**	**5 W/kg**	**10 W/kg**
Natural deaths	14	7	11	11
Animals surviving to study termination	67[f]	74[h]	70[i]	73[j]
Percent probability of survival at end of study[c]	74	80	77	80
Mean survival (days)[d]	704	715	711	712
Survival analysis[e]	P = 0.476N	P = 0.420N	P = 0.709N	P = 0.405N

[a]Excluded from survival analysis.
[b]Censored in the survival analysis.
[c]Kaplan-Meier determinations.
[d]Mean of all deaths (uncensored, censored, and terminal euthanasia).
[e]The result of the life table trend test[158] is in the sham control column, and the results of the life table pairwise comparisons[157] with the sham controls are in the exposed group columns. A negative trend or lower mortality in an exposure group is indicated by **N**.
[f]Includes one animal that died during the last week of the study.
[g]Includes four animals that died during the last week of the study.
[h]Includes four animals that died during the last week of the study; two of these were censored in the survival analysis.
[i]Includes two animals that died during the last week of the study; one of these was censored in the survival analysis.
[j]Includes one animal that died during the last week of the study; this animal was censored in the survival analysis.

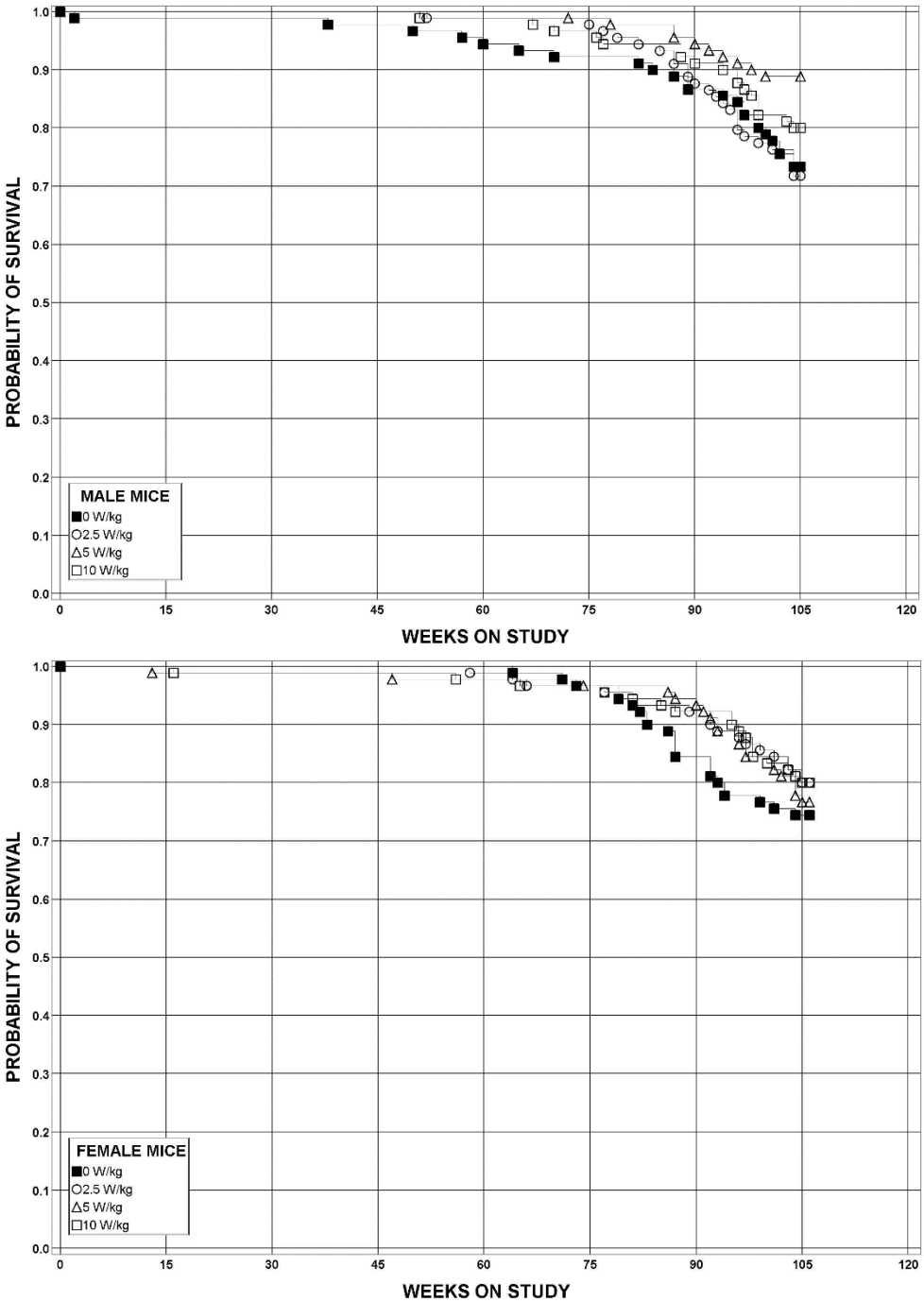

Figure 7. Kaplan-Meier Survival Curves for Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

Table 5. Mean Body Weights and Survival of Male Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

	Sham Control		2.5 W/kg			5 W/kg			10 W/kg		
Day	Av. Wt. (g)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors
0	20.6	105	20.4	99.1	105	20.4	99.4	105	20.4	99.0	105
8	21.9	104	22.0	100.4	104	21.8	99.5	105	21.9	100.2	105
15	22.9	104	23.1	100.7	104	22.8	99.4	105	23.1	100.6	105
22	24.1	104	24.4	101.4	104	24.0	99.7	105	23.9	99.1	105
29	25.1	104	25.4	101.2	104	25.0	99.6	105	24.8	98.5	105
36	26.3	104	26.2	99.9	104	26.1	99.5	105	25.7	98.0	105
43	27.3	104	27.1	99.3	104	27.2	99.5	105	26.4	96.7	105
50	28.1	104	27.8	99.1	104	28.1	100.2	105	27.5	98.1	105
57	29.3	104	28.9	98.5	104	29.3	99.9	105	28.7	97.8	105
64	30.5	104	29.6	97.2	104	30.3	99.4	105	29.7	97.2	105
71	31.7	104	30.8	97.3	104	31.7	100.1	105	30.9	97.5	105
79	32.9	104	31.8	96.6	104	32.9	100.1	105	32.1	97.5	105
86	33.6	104	33.0	98.3	104	33.8	100.5	105	32.7	97.2	105
93	34.3	94	34.0	99.0	94	34.7	101.2	95	33.6	98.0	95
121	38.6	89	38.5	99.5	89	39.4	101.9	90	38.5	99.7	90
149	42.0	89	42.2	100.6	89	42.1	100.2	90	42.8	101.9	90
177	44.3	89	44.4	100.3	89	44.7	100.9	90	44.8	101.0	90
205	46.0	89	46.3	100.7	89	46.4	100.8	90	46.1	100.3	90
233	47.3	89	47.1	99.7	89	47.3	100.1	90	46.7	98.8	90
261	47.6	89	47.9	100.8	89	47.9	100.6	90	47.1	99.0	90
289	48.2	88	48.6	100.7	89	48.5	100.6	90	47.7	98.9	90
317	48.8	88	49.1	100.7	89	49.1	100.6	90	48.2	98.8	90
345	49.4	88	49.7	100.7	89	49.7	100.6	90	48.6	98.4	90
373	50.0	87	50.3	100.6	88	50.2	100.4	90	49.2	98.3	89
401	50.4	86	51.0	101.0	88	51.0	101.0	90	49.7	98.4	89
429	50.7	85	51.2	100.9	88	51.5	101.4	90	50.1	98.8	89
457	51.1	84	51.7	101.1	88	51.9	101.5	90	50.3	98.4	89
485	51.5	84	52.1	101.3	88	52.3	101.5	90	51.1	99.3	88
513	50.5	83	51.4	101.8	88	52.0	103.0	89	50.6	100.2	87
541	49.7	83	50.7	102.0	86	51.2	103.0	89	50.6	101.7	85
569	50.4	82	51.1	101.5	85	51.8	102.8	88	51.2	101.8	85
597	50.9	81	51.8	101.7	83	52.1	102.3	88	51.5	101.3	85
625	50.7	78	51.6	101.7	79	52.1	102.7	86	51.5	101.5	82
639	49.8	78	51.5	103.6	78	51.9	104.3	85	51.1	102.7	82
653	49.0	78	51.1	104.3	75	51.9	105.8	84	50.8	103.6	82
667	49.0	76	51.0	104.0	71	52.0	106.1	82	50.5	103.0	81
681	49.2	74	51.1	103.9	69	51.7	105.0	82	49.8	101.2	77
695	48.7	71	50.6	104.0	68	51.1	104.9	81	50.0	102.7	74
709	48.5	69	50.3	103.6	67	50.6	104.3	80	49.1	101.3	74
723	48.4	67	50.6	104.6	65	50.0	103.4	80	48.9	101.1	73
Mean for Weeks											
1–13	27.3		27.0	99.2		27.2	99.8		26.8	98.3	
14–52	44.7		44.8	100.3		45.0	100.8		44.4	99.5	
53–105	49.9		51.1	102.4		51.5	103.1		50.4	100.9	

Table 6. Mean Body Weights and Survival of Female Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

	Sham Control		2.5 W/kg			5 W/kg			10 W/kg		
Day	Av. Wt. (g)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors
0	17.4	105	17.2	99.1	105	17.5[a]	100.3	104	17.3	99.6	105
8	18.4	105	18.3	99.5	105	18.5	100.9	105	18.4	100.3	105
15	19.4	105	19.4	99.6	105	19.4	99.6	105	19.3	99.3	105
22	20.2	105	20.3	100.4	105	20.2	99.8	105	20.2	99.8	105
29	20.8	105	20.9	100.5	105	20.9	100.4	105	20.8	99.8	105
36	21.5	105	21.5	99.9	105	21.7	100.9	105	21.5	99.9	105
43	22.0	105	21.9	99.4	105	21.9	99.8	105	21.8	99.4	105
50	22.5	105	22.3	98.8	105	22.5	99.9	105	22.5	100.1	105
57	22.8	105	22.6	99.0	105	22.9	100.6	105	22.7	99.8	105
64	23.3	105	23.3	99.7	105	23.7	101.4	105	23.5	100.7	105
71	23.4	105	23.6	101.0	105	24.1	102.9	105	24.1	102.9	105
79	23.9	105	24.2	101.0	105	24.4	102.1	105	24.6	102.9	105
86	24.0	105	24.3	101.4	105	24.5	101.9	104	24.7	102.8	105
93	24.3	95	24.4	100.3	95	25.2	103.6	94	25.0	103.0	95
121	26.3	90	26.8	101.7	90	28.2	107.2	89	27.3	103.6	89
149	28.8	90	29.3	101.6	90	30.6	106.2	89	30.4	105.5	89
177	30.8	90	31.7	103.1	90	33.6	109.3	89	33.4	108.5	89
205	33.4	90	34.9	104.6	90	36.7	109.9	89	36.1	108.2	89
233	36.8	90	37.3	101.5	90	39.7	108.0	89	39.0	106.0	89
261	38.4	90	38.9	101.3	90	41.5	107.9	89	41.6	108.2	89
289	40.3	90	40.3	100.1	90	43.2	107.1	89	42.7	106.0	89
317	42.3	90	42.8	101.4	90	45.4	107.6	89	45.3	107.2	89
345	45.0	90	45.3	100.7	90	47.7	106.0	88	47.2	104.8	89
373	47.6	90	47.7	100.1	90	49.6	104.2	88	49.1	103.0	89
401	49.9	90	49.3	98.7	90	51.9	103.9	88	51.2	102.5	88
429	51.4	90	51.3	99.9	89	53.4	103.9	88	52.4	102.1	88
457	53.3	89	52.6	98.7	88	54.5	102.3	88	53.7	100.8	87
485	55.0	89	53.9	98.1	87	55.6	101.1	88	55.4	100.7	87
513	54.5	87	53.3	97.8	87	54.1	99.3	88	54.1	99.2	87
541	51.9	87	51.4	99.1	86	52.6	101.4	87	52.2	100.7	86
569	52.2	83	52.0	99.7	84	53.6	102.7	87	53.0	101.5	85
597	55.3	80	54.4	98.4	84	55.0	99.5	87	54.8	99.2	84
625	56.3	76	55.0	97.8	83	55.5	98.6	85	56.0	99.6	83
639	54.8	75	54.0	98.6	82	54.6	99.6	83	54.5	99.6	83
653	54.5	71	53.4	97.9	80	54.9	100.8	80	53.8	98.7	83
667	55.1	70	53.2	96.6	79	54.8	99.6	80	53.5	97.2	81
681	54.6	70	52.7	96.5	78	54.2	99.2	76	53.4	97.8	77
695	54.0	69	52.1	96.3	77	53.1	98.2	76	52.8	97.7	76
709	53.7	68	52.1	96.9	76	52.0	96.8	74	51.8	96.5	75
723	53.0	68	51.7	97.6	74	51.8	97.7	71	52.0	98.1	74
737	52.2	67	51.2	98.1	72	51.1	97.8	69	51.6	98.9	72
Mean for Weeks											
1-13	21.5		21.5	99.9		21.7	100.8		21.6	100.6	
14-52	34.6		35.2	101.6		37.2	107.3		36.8	106.1	
53-107	53.3		52.3	98.2		53.5	100.4		53.1	99.7	

[a]One animal not weighed.

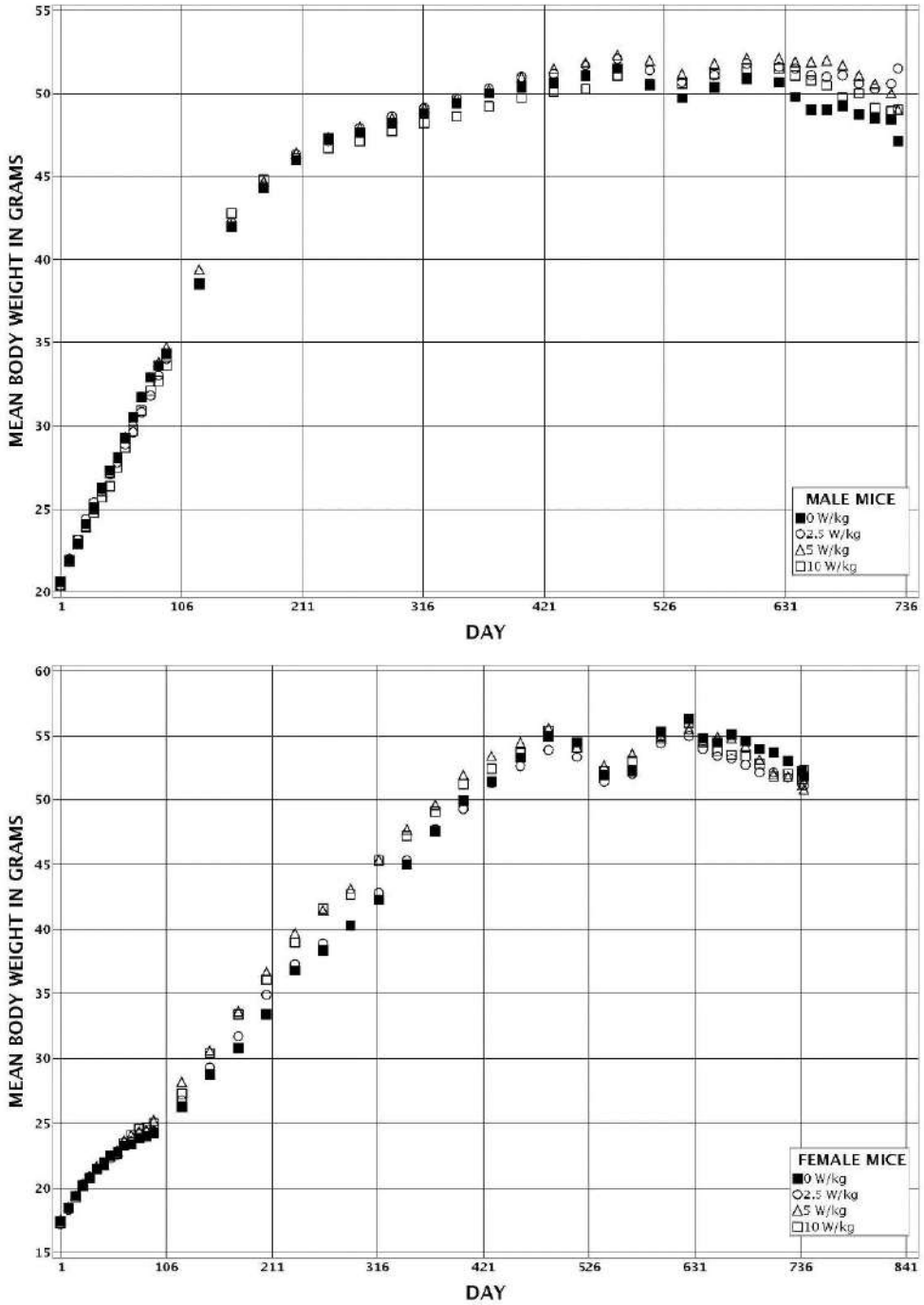

Figure 8. Growth Curves for Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

14-week Interim Evaluation

There were no changes to the hematology variables attributable to GSM-modulated RFR exposure (Table F-1).

At the 14-week interim evaluation, mean body weights of exposed groups of males and females were similar to those of the sham controls (Table G-2). In males, the absolute right kidney weights were significantly lower (7%) in the 5 and 10 W/kg groups compared to the sham

controls, and the absolute left kidney weight was significantly lower (12%) in the 10 W/kg group (Table G-2). The absolute liver weights of 5 and 10 W/kg males were significantly lower (10%) and the relative liver weight was significantly lower in 5 W/kg males. These organ weight changes were considered small changes and were not accompanied by exposure-related histopathologic lesions. In 10 W/kg females, there were significantly lower relative weights in the brain and right kidney (Table G-2); these changes were not accompanied by significant changes in absolute weights and were not considered toxicologically important. The absolute thymus weight of 10 W/kg females was 20% higher compared to the sham controls, but this was not correlated with any histopathologic lesions in the thymus.

In males, there were no exposure-related effects on reproductive organ weights, testis spermatid concentrations, caudal epididymal sperm concentrations, or sperm motility (Table H-1). In females, there were no exposure-related effects on estrous cycle length, number of cycling females, or relative amount of time spent in the estrous stages (Table H-2, Table H-3; Figure H-1).

In the liver, a significantly higher incidence of focal inflammation occurred in 5 W/kg males (sham control, 0/10; 2.5 W/kg, 2/10; 5 W/kg, 4/10; 10 W/kg, 0/10; Table A-5). Focal inflammation is commonly seen in B6C3F1/N mice, and consisted of small clusters of mixed inflammatory cells, predominantly lymphocytes with fewer macrophages and an occasional neutrophil. There was no zonal pattern to this finding and the inflammation was randomly scattered within the hepatic parenchyma. All of the lesions were of minimal severity that typically consisted of one to three small areas of inflammation, and they were not considered biologically relevant.

Pathology and Statistical Analyses

This section describes the statistically significant or potentially biologically noteworthy changes in the incidences of malignant lymphoma and neoplasms and/or nonneoplastic lesions of the skin, lung, mediastinum, and ovary in the 2-year study. Summaries of the incidences of neoplasms and nonneoplastic lesions, statistical analyses of primary neoplasms that occurred with an incidence of at least 5% in at least one animal group, and historical incidences for the neoplasms mentioned in this section are presented in Appendix A for male mice and Appendix B for female mice.

Skin (Subcutaneous Tissue): Fibrosarcoma, sarcoma, and malignant fibrous histiocytoma are all neoplasms of mesenchymal stem cell origin, and as such, the combined incidences of these tumors were evaluated, as well as the incidences of malignant fibrous histiocytoma alone. The International Harmonization of Nomenclature and Diagnostic Criteria for Lesions in Rats and Mice (INHAND) project currently refers to malignant fibrous histiocytomas as pleomorphic fibrosarcomas, furthering the concept that these neoplasms should be considered together. The incidences of malignant fibrous histiocytoma were higher in 5 and 10 W/kg males, although not significantly or in an exposure concentration-related manner (Table 7, Table A-1, Table A-2); however, the incidences exceeded the overall historical control ranges for malignant fibrous histiocytoma (Table 7, Table A-3). The combined incidences of fibrosarcoma, sarcoma, or malignant fibrous histiocytoma were also increased in the 5 and 10 W/kg males, although still not in a statistically significant or exposure concentration-dependent manner. In males, all but one of the malignant fibrous histiocytomas occurred on the tail; the remaining neoplasm (in a 5 W/kg animal) was located on the pinna of the ear; this animal also had a neoplasm on the tail

and was recorded as having malignant fibrous histiocytoma, multiple. The two tumors in that one animal were small, well circumscribed lesions, distinct in appearance from one another, and lacking in features that would indicate metastatic lesions; hence they were recorded as multiple rather than one neoplasm with a metastasis. Malignant fibrous histiocytomas can have a variable appearance. In general, all the malignant fibrous histiocytomas had a portion of the neoplasm that was composed of spindle-shaped cells arranged in interlacing or irregular bundles or whorls amongst a background of varying amounts of collagen and a sizable population of cells resembling histiocytes – large cells with abundant eosinophilic cytoplasm and small basophilic nuclei. Multinucleated cells were present in most of the tumors, but were more abundant in the neoplasm on the ear. Several of the neoplasms on the tail had areas of pigment in the section – possibly from the tail tattoo. The single malignant fibrous histiocytoma that occurred in a sham control male metastasized throughout the abdominal cavity, involving the liver, stomach, mesentery, adrenal gland, and seminal vesicle, as well as being found in the mesenteric lymph nodes and skeletal muscle. None of the other neoplasms had distant metastases.

Table 7. Incidences of Neoplasms of the Skin (Subcutaneous Tissue) in Male Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Number Examined Microscopically	90	89	90	90
Malignant Fibrous Histiocytoma, Multiple[a]	0	0	1 (1%)	0
Malignant Fibrous Histiocytoma (includes multiple)[b]				
Overall rate[c]	1/90 (1%)	0/89 (0%)	5/90 (6%)	3/90 (3%)
Adjusted rate[d]	1.2%	0.0%	5.8%	3.6%
Terminal rate[e]	0/66 (0%)	0/63 (0%)	4/80 (5%)	3/72 (4%)
First incidence (days)	674	–[g]	654	729 (T)
Poly-3 test[f]	P = 0.127	P = 0.499N	P = 0.124	P = 0.321
Fibrosarcoma, Sarcoma, or Malignant Fibrous Histiocytoma[h]				
Overall rate	1/90 (1%)	1/89 (1%)	5/90 (6%)	4/90 (4%)
Adjusted rate	1.2%	1.2%	5.8%	4.7%
Terminal rate	0/66 (0%)	0/63 (0%)	4/80 (5%)	3/72 (4%)
First incidence (days)	674	523	654	488
Poly-3 test	P = 0.093	P = 0.758N	P = 0.124	P = 0.197

T = terminal euthanasia.
[a]Number of animals with neoplasm.
[b]Historical control incidence for 2-year studies (all studies except RFR) (mean ± standard deviation): 1/499 (0.2% ± 0.6%), range 0%–2%.
[c]Number of animals with neoplasm per number of animals necropsied.
[d]Poly-3 estimated neoplasm incidence after adjustment for intercurrent mortality.
[e]Observed incidence at terminal euthanasia.
[f]Beneath the sham control incidence is the P value associated with the trend test. Beneath the exposed group incidence are the P values corresponding to pairwise comparisons between the sham controls and that exposed group. The Poly-3 test accounts for differential mortality in animals that do not reach terminal euthanasia. A lower incidence in an exposure group is indicated by **N**.
[g]Not applicable; no neoplasms in animal group.
[h]Historical control incidence: 4/499 (0.8% ± 1.0%), range 0%–2%.

The single occurrences of sarcoma in a 2.5 W/kg male (sham control, 0/90; 2.5 W/kg, 1/89; 5 W/kg, 0/90; 10 W/kg, 0/90) and fibrosarcoma in a 10 W/kg male (0/90, 0/89, 0/90, 1/90) were histologically much different from the malignant fibrous histiocytomas (Table A-1). They were much larger neoplasms, with large areas of necrosis. They were poorly circumscribed and consisted of interlacing bundles of elongated cells. Nuclei were long and oval and typically vesicular, in comparison to the small, often round, densely basophilic nuclei found in the malignant fibrous histiocytomas. There was no population of histiocyte-like cells in the sarcoma or the fibrosarcoma. The fibrosarcoma had evidence of collagen fibers within the neoplasm, indicating a fibrosarcoma, but in the case of the sarcoma, the tumor was anaplastic and lacked any kind of specific diagnostic features allowing it to be classified any further than sarcoma. Neither of these neoplasms occurred on the tail.

Lung: There was a significant positive trend in the incidences of alveolar/bronchiolar adenoma or carcinoma (combined) in males (Table 8, Table A-2). The incidences of focal alveolar epithelial hyperplasia were similar in all groups of males (6/90, 8/89, 8/90, 7/90; Table A-5). Alveolar/bronchiolar adenomas were discrete, expansile proliferations of cuboidal to columnar cells supported by a fine fibrovascular stroma arranged in solid nests or papillary fronds projecting into alveolar spaces and causing compression of the surrounding parenchyma.

Alveolar/bronchiolar carcinomas were usually larger than adenomas and tended to be poorly demarcated and locally invasive. They were composed of cuboidal to columnar epithelial cells that displayed moderate to marked pleomorphism and lacked a normal orderly arrangement, with multiple layers and piling up of cells. The neoplastic cells were arranged in papillary arrangements or solid sheets of cells; most carcinomas contained both growth patterns. Occasional mitoses were present.

Malignant Lymphoma: Compared to the sham controls, all exposed groups of females had higher incidences of malignant lymphoma and the incidences in the 2.5 and 5 W/kg groups were significantly higher (Table 9, Table B-1, Table B-2). The sham control group had a low incidence of malignant lymphoma compared to the range seen in historical controls (Table 9, Table B-3). All of the incidences in the exposed groups fell within the overall historical control range. Malignant lymphoma involved many organs, most frequently the spleen, lymph nodes, thymus, lung, kidney, liver, and bone marrow, and was characterized by the effacement of normal architecture by a monomorphic population of neoplastic lymphocytes, which tended to be larger than normal lymphocytes. In spleens with malignant lymphoma, there was a loss of individual follicles and periarteriolar lymphoid sheaths, as the enlarged white pulp became one solid sheet of neoplastic cells sometimes leading to the gross enlargement of the organ. In the lymph nodes and thymus, malignant lymphoma led to the loss of distinguishable cortical and medullary regions, with the entire node appearing to contain only a single type of cell. Involved lymph nodes were typically grossly enlarged. In the liver and kidney, aggregates of neoplastic lymphocytes disrupted the normal arrangement of the paren-chyma, and in the lungs, neoplastic lymphocytes were often found expanding the bronchial-associated lymphoid tissue. Malignant lymphoma in the bone marrow resulted in a hypercellular marrow cavity with a monotonous population of malignant lymphocytes rather than the typical mix of erythrocytes and leukocytes in various stages of maturity.

Other Tissues: Several tissues had significantly increased incidences of lesions in one, or even two exposed groups of males or females. Many of them, such as lymphocytic infiltration or

inflammation in various tissues, are common findings in aged mice and the incidences and severities recorded in this study were not considered exposure related. The incidence of other lesions lacked an exposure concentration response and were considered sporadic occurrences or of unknown importance.

Table 8. Incidences of Alveolar/bronchiolar Neoplasms in Male Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Number Examined Microscopically	90	89	90	90
Alveolar/bronchiolar Adenoma, Multiple[a]	2	0	2	1
Alveolar/bronchiolar Adenoma (includes multiple)[b]				
Overall rate[c]	13/90 (14%)	13/89 (15%)	18/90 (20%)	16/90 (18%)
Adjusted rate[d]	16.0%	16.0%	20.7%	19.0%
Terminal rate[e]	9/66 (14%)	10/63 (16%)	16/80 (20%)	14/72 (19%)
First incidence (days)	488	663	604	658
Poly-3 test[f]	P = 0.297	P = 0.583	P = 0.279	P = 0.380
Alveolar/bronchiolar Carcinoma, Multiple	2	0	1	1
Alveolar/bronchiolar Carcinoma (includes multiple)[g]				
Overall rate	13/90 (14%)	12/89 (13%)	16/90 (18%)	18/90 (20%)
Adjusted rate	16.1%	14.7%	18.5%	21.2%
Terminal rate	12/66 (18%)	8/63 (13%)	16/80 (20%)	14/72 (19%)
First incidence (days)	568	594	729 (T)	614
Poly-3 test	P = 0.165	P = 0.488N	P = 0.418	P = 0.259
Alveolar/bronchiolar Adenoma or Carcinoma[h]				
Overall rate	23/90 (26%)	24/89 (27%)	32/90 (36%)	34/90 (38%)
Adjusted rate	28.1%	29.2%	36.8%	39.9%
Terminal rate	18/66 (27%)	17/63 (27%)	30/80 (38%)	28/72 (39%)
First incidence (days)	488	594	604	614
Poly-3 test	P = 0.040	P = 0.506	P = 0.149	P = 0.074

T = terminal euthanasia.
[a]Number of animals with neoplasm.
[b]Historical control incidence for 2-year studies (all studies except RFR) (mean ± standard deviation): 71/499 (14.2% ± 5.7%), range 8%–24%.
[c]Number of animals with neoplasm per number of animals with lung examined microscopically.
[d]Poly-3 estimated neoplasm incidence after adjustment for intercurrent mortality.
[e]Observed incidence at terminal euthanasia.
[f]Beneath the sham control incidence is the P value associated with the trend test. Beneath the exposed group incidence are the P values corresponding to pairwise comparisons between the sham controls and that exposed group. The Poly-3 test accounts for differential mortality in animals that do not reach terminal euthanasia. A lower incidence in an exposure group is indicated by **N**.
[g]Historical control incidence: 53/499 (10.6% ± 4.5%), range 4%–20%.
[h]Historical control incidence: 119/499 (23.8% ± 5.5%), range 16%–34%.

Table 9. Incidences of Malignant Lymphoma in Female Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Malignant Lymphoma[a]				
Overall rate[b]	2/90 (2%)	13/90 (14%)	9/90 (10%)	6/90 (7%)
Adjusted rate[c]	2.5%	15.6%	10.7%	7.1%
Terminal rate[d]	1/67 (1%)	12/72 (17%)	5/69 (7%)	3/72 (4%)
First incidence (days)	604	731	516	590
Poly-3 test[e]	P = 0.474	P = 0.004	P = 0.035	P = 0.153

[a]Historical control incidence for 2-year studies (all studies except RFR) (mean ± standard deviation): 87/500 (17.4% ± 7.2%), range 10%–36%.
[b]Number of animals with neoplasm per number of animals necropsied.
[c]Poly-3 estimated neoplasm incidence after adjustment for intercurrent mortality.
[d]Observed incidence at terminal euthanasia.
[e]Beneath the sham control incidence is the P value associated with the trend test. Beneath the exposed group incidence are the P values corresponding to pairwise comparisons between the sham controls and that exposed group. The Poly-3 test accounts for differential mortality in animals that do not reach terminal euthanasia.

Two hibernomas of the mediastinum occurred in 5 W/kg males (0, 0, 2, 0; Table A-1). These are unusual neoplasms of brown adipose tissue. Hibernomas were grossly observed tumors; histologically they were composed of round cells with moderate amounts of cytoplasm filled with tiny vacuoles, and small, round nuclei. Two benign ovarian teratomas occurred in 5 W/kg females, and one in 10 W/kg females (0/75, 0/86, 2/82, 1/80; Table B-1). Neither of these neoplasms occurred in the sham controls, nor have they occurred in the overall (except RFR study) historical control populations [males: mediastinum, hibernoma (0/499); females: ovary, benign teratoma (0/495)]. However, benign teratomas have been reported in the literature to occur in B6C3F1 mice[192]. Both the hibernomas and the teratomas were considered sporadic occurrences of rare neoplasms, and while unusual, were not considered exposure related.

CDMA

Twenty-eight-day Study

All mice survived to the end of the study (Table 10). Weekly mean body weights of exposed groups of males and females were similar to those of the sham controls at all time points (Table 10; Figure 9). There were no clinical signs related to exposure to CDMA-modulated RFR.

Similar to what was seen in mice exposed to GSM-modulated RFR, body temperatures were significantly higher in males and significantly lower in females at several time points (Table 11).

Table 10. Mean Body Weights and Survival of Mice Exposed to CDMA-modulated Cell Phone RFR for 28 Days

	Sham Control		5 W/kg			10 W/kg			15 W/kg		
Day	Av. Wt. (g)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors
Male											
1	20.2	10	20.4	100.7	10	20.4	101.0	10	20.9	103.2	10
8	21.8	10	21.8	100.0	10	22.2	101.6	10	22.4	102.4	10
15	22.8	10	22.4	98.3	10	23.0	100.9	10	23.3	102.3	10
22	24.0	10	23.5	98.0	10	23.9	99.6	10	24.2	101.0	10
29	24.9	10	24.3	97.6	10	25.2	101.2	10	25.1	101.1	10
Female											
1	18.1	10	18.2	100.5	10	17.9	99.2	10	17.6	97.5	10
8	18.9	10	19.0	100.8	10	18.7	99.3	10	18.7	99.0	10
15	20.1	10	20.1	99.6	10	20.0	99.4	10	19.8	98.2	10
22	21.0	10	21.0	99.9	10	20.8	99.1	10	20.5	97.4	10
30	21.7	10	21.7	99.7	10	21.6	99.4	10	21.2	97.5	10

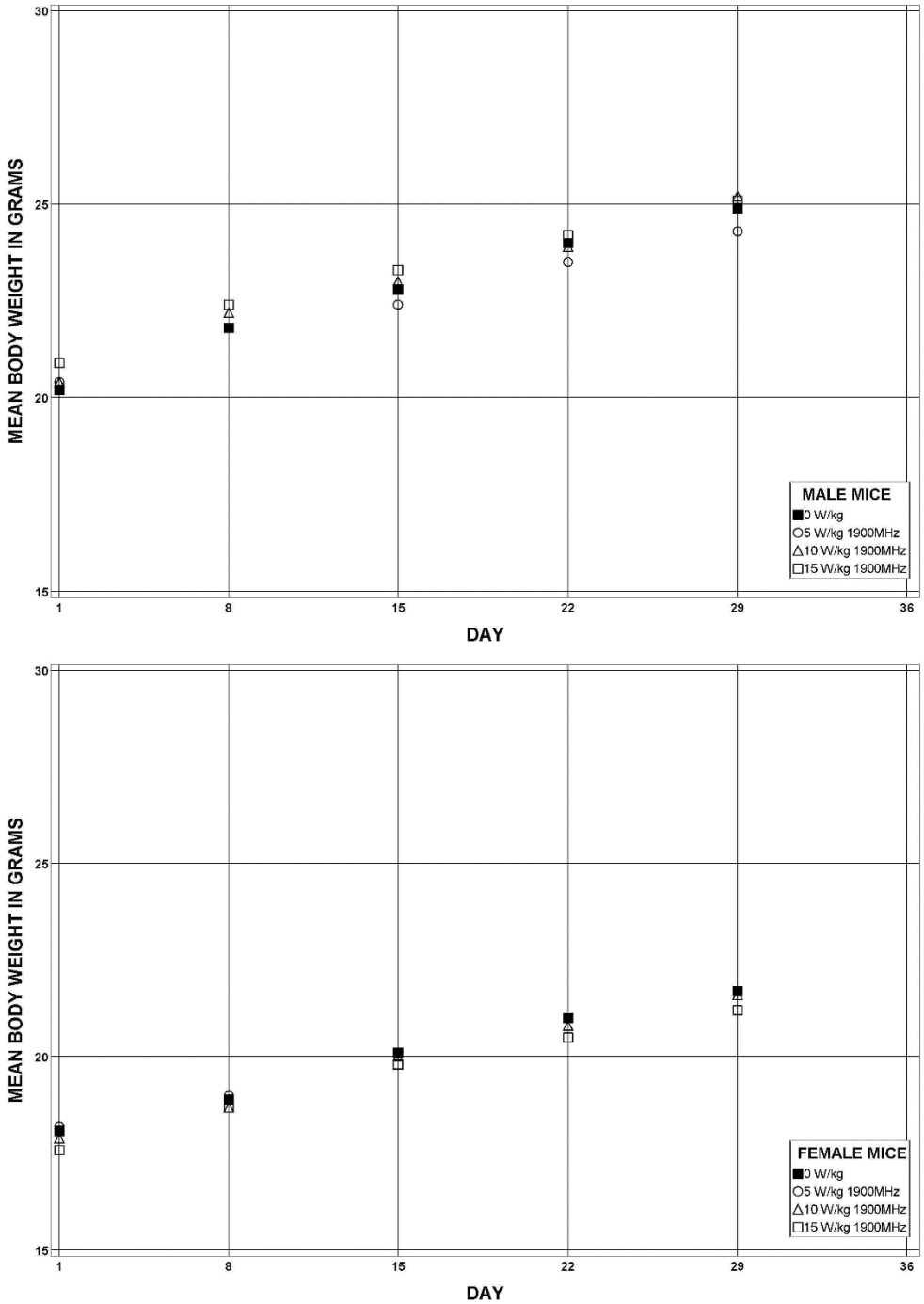

Figure 9. Growth Curves for Mice Exposed to CDMA-modulated Cell Phone RFR for 28 Days

Table 11. Mean Body Temperatures of Mice Exposed to CDMA-modulated Cell Phone RFR for 28 Days[a]

	Sham Control		5 W/kg		10 W/kg		15 W/kg	
Day	Temperature (°C)	No. Measured	Temperature (°C)	No. Measured	Temperature (°C)	No. Measured	Temperature (°C)	No. Measured
Male								
0	37.0 ± 0.2	10	37.0 ± 0.1	10	38.0 ± 0.2**	10	37.8 ± 0.2**	10
2	35.7 ± 0.1	10	36.1 ± 0.1	10	37.0 ± 0.3**	10	36.5 ± 0.2**	10
4	36.2 ± 0.2	10	36.7 ± 0.2	10	37.0 ± 0.2**	10	37.1 ± 0.2**	10
7[b]	36.6 ± 0.2	9	36.4 ± 0.2	10	37.3 ± 0.3	10	37.3 ± 0.2	10
14[b]	35.5 ± 0.3	10	35.8 ± 0.1	10	36.1 ± 0.2	10	36.0 ± 0.1	10
17	36.0 ± 0.3	10	36.2 ± 0.3	10	36.8 ± 0.4	10	37.2 ± 0.3*	10
20	36.5 ± 0.3	10	36.4 ± 0.2	10	37.3 ± 0.3*	10	37.6 ± 0.2**	10
27	35.8 ± 0.4	9	36.5 ± 0.3	10	37.4 ± 0.3**	10	36.8 ± 0.3	10
2–27[c]	36.0 ± 0.2	10	36.3 ± 0.1	10	37.1 ± 0.1**	10	36.9 ± 0.1**	10
Female								
0	38.1 ± 0.1	10	37.5 ± 0.1*	9	38.3 ± 0.1	10	38.0 ± 0.2	10
2	37.5 ± 0.2	10	37.0 ± 0.2	9	38.1 ± 0.2	10	37.5 ± 0.2	10
4	37.0 ± 0.2	10	37.2 ± 0.2	10	37.7 ± 0.2	10	37.5 ± 0.2	10
7[b]	38.6 ± 0.1	10	37.9 ± 0.2**	9	38.0 ± 0.1*	10	38.3 ± 0.1	10
14[b]	36.9 ± 0.1	10	36.5 ± 0.2	9	37.0 ± 0.1	10	37.0 ± 0.2	10
17	37.9 ± 0.1	10	37.1 ± 0.2**	10	37.6 ± 0.1	10	37.4 ± 0.2	10
20	37.7 ± 0.2	10	37.2 ± 0.1	10	37.5 ± 0.2	10	37.9 ± 0.1	10
27	37.8 ± 0.1	10	37.4 ± 0.3	10	37.9 ± 0.2	10	38.0 ± 0.3	10
2–27[c]	37.6 ± 0.1	10	37.2 ± 0.1**	10	37.7 ± 0.1	10	37.7 ± 0.1	10

*Significantly different ($P \leq 0.05$) from the sham control group by Williams' or Dunnett's test.
**$P \leq 0.01$.
[a]Temperatures are given as mean ± standard error.
[b]All temperatures were recorded within 5 minutes of the exposure cessation, except for the measurements on days 7 and 14, which were recorded at least 1 hour after exposure.
[c]Average of days 2 to 27, excluding days 7 and 14.

There were no exposure-related effects on organ weights of males exposed to CDMA-modulated RFR (Table G-3). The absolute kidney weight of 15 W/kg females was significantly less (12%) than that of the sham controls (Table G-3); however, because there was no similar effect on relative kidney weight and no associated histopathologic findings, the biological significance of this finding was unknown.

There were no histopathologic lesions related to the effects of exposure to CDMA-modulated RFR.

Exposure Level Selection Rationale: In male and female mice exposed for 5 days to RFR up to 12 W/kg, only sporadic increases were observed in body temperature, regardless of the sex or age of the animals[144]. Because no significant effects of RFR were observed in body temperature

at 12 W/kg, a higher upper exposure level was selected for the 28-day studies. Due to limits on the maximum capacity of the exposure system to generate high RF fields, the maximum achievable exposure level capacity was 15 W/kg, which was selected as the highest exposure level for the 28-day studies. Selection of the highest exposure level for the 2-year studies was also limited by the power capacity of the exposure system to generate maximum RF fields. Based on these limitations and increased body temperatures at various time points that were similarly observed at 10 and 15 W/kg in the 28-day studies, the exposure levels selected for the 2-year studies were 2.5, 5, and 10 W/kg.

Two-year Study

Survival

Estimates of 2-year survival probabilities for male and female mice are shown in Table 12 and in the Kaplan-Meier survival curves (Figure 10). Survival was significantly higher in 2.5 W/kg males compared to that in the sham controls. Survival of males and females in all other exposed groups was generally similar to that of the sham controls.

Body Weights and Clinical Observations

Mean body weights of exposed groups of males and females were similar to those of the sham controls throughout the study (Table 13, Table 14; Figure 11). In males, there were higher occurrences of the clinical signs mass-torso/lateral and mass-torso/ventral in the 10 W/kg group. In females, more occurrences of ruffled fur were recorded in the 5 and 10 W/kg groups and more occurrences of thin were recorded in all exposed groups. These findings were not correlated with differences in body weights or incidences of neoplasms in exposed animals.

Table 12. Survival of Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Male				
Animals initially in study	105	106	105	105
14-week interim evaluation[a]	15	15	15	15
Accidental death[b]	0	0	1	0
Moribund	8	2	5	3
Natural deaths	16	6	13	16
Animals surviving to study termination	66	83	71	71
Percent probability of survival at end of study[c]	73	91	80	79
Mean survival (days)[d]	687	715	706	704
Survival analysis[e]	P = 1.000N	P = 0.003N	P = 0.343N	P = 0.482N
Female				
Animals initially in study	105	104	105	105
14-week interim evaluation[a]	15	15	15	15
Moribund	9	5	4	4
Natural deaths	14	9	16	14

	Sham Control	**2.5 W/kg**	**5 W/kg**	**10 W/kg**
Animals surviving to study termination	67[f]	75[g]	70[h]	72[h]
Percent probability of survival at end of study[c]	74	83	77	79
Mean survival (days)[d]	704	715	715	712
Survival analysis[e]	P = 0.758N	P = 0.168N	P = 0.702N	P = 0.517N

[a]Excluded from survival analysis.
[b]Censored in the survival analysis.
[c]Kaplan-Meier determinations.
[d]Mean of all deaths (uncensored, censored, and terminal euthanasia).
[e]The result of the life table trend test[158] is in the sham control column, and the results of the life table pairwise comparisons[157] with the sham controls are in the exposed group columns. A negative trend or lower mortality in an exposure group is indicated by **N**.
[f]Includes one animal that died during the last week of the study.
[g]Includes three animals that died during the last week of the study; one of these was censored in the survival analysis.
[h]Includes one animal that died during the last week of the study; this animal was censored in the survival analysis.

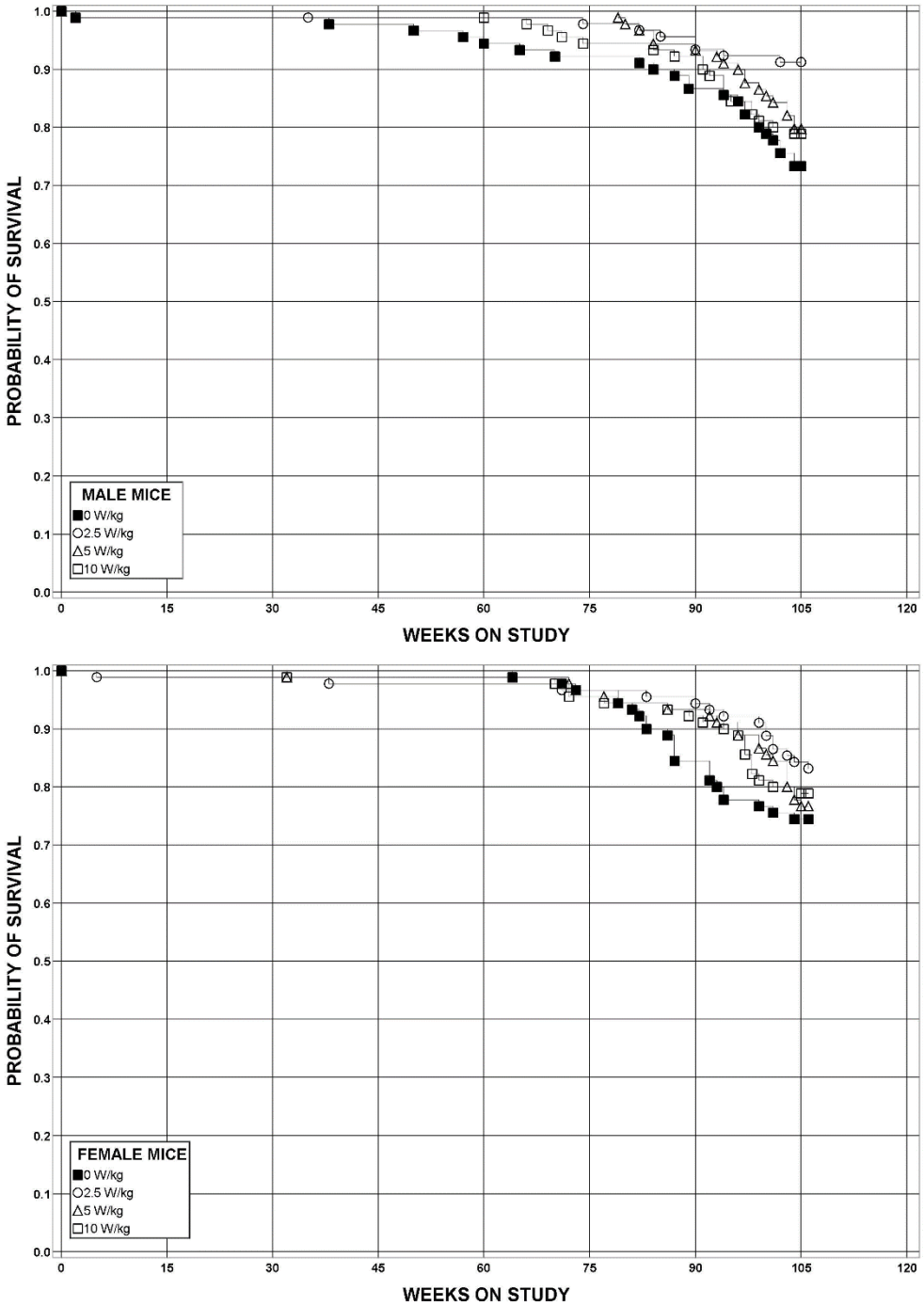

Figure 10. Kaplan-Meier Survival Curves for Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

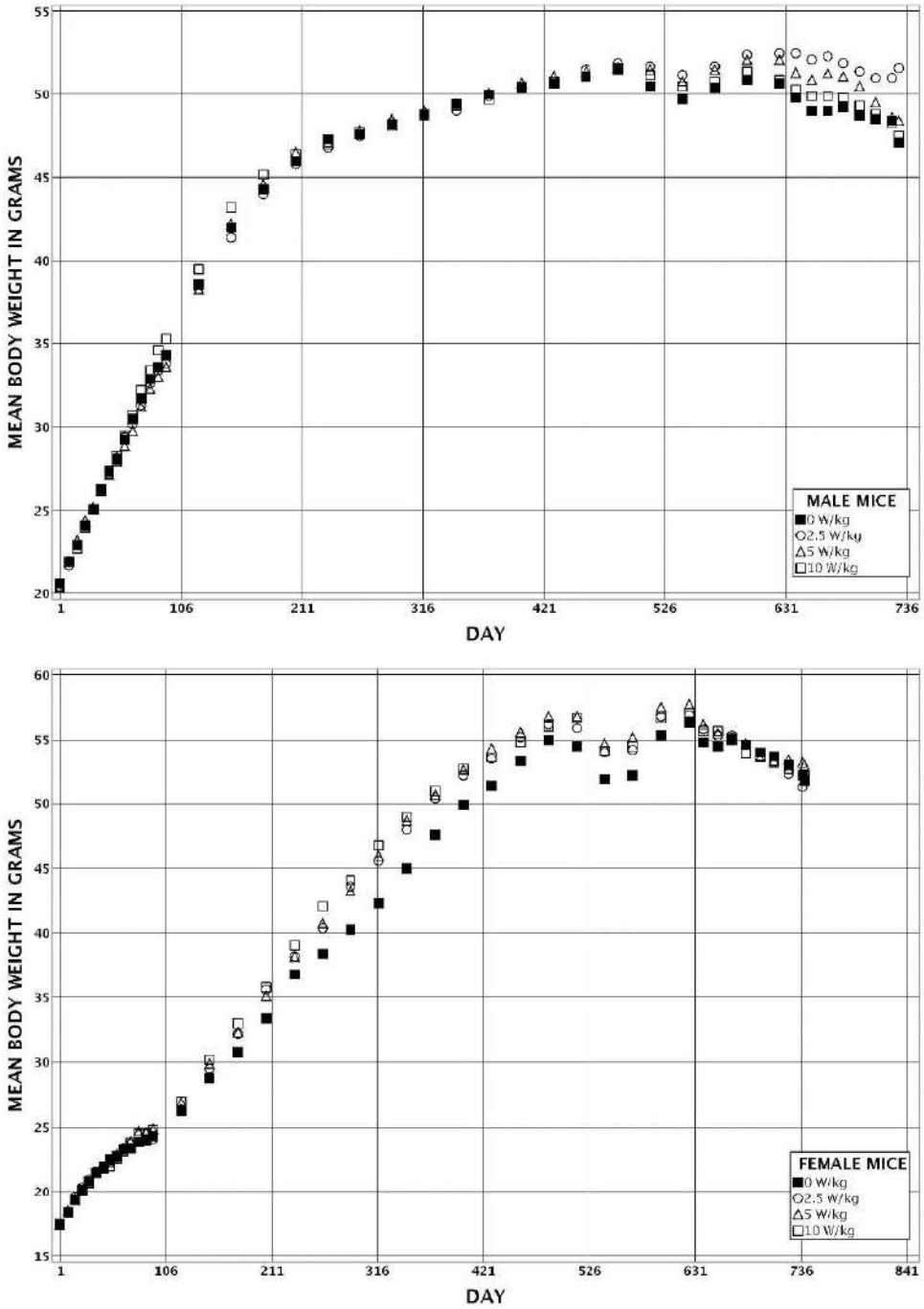

Figure 11. Growth Curves for Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

Table 13. Mean Body Weights and Survival of Male Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

	Sham Control		2.5 W/kg			5 W/kg			10 W/kg		
Day	Av. Wt. (g)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors
0	20.6	105	20.4	99.1	106	20.3	99.0	105	20.4	99.3	105
8	21.9	104	21.7	99.0	106	21.9	100.0	105	21.9	100.2	105
15	22.9	104	22.9	99.9	106	23.2	101.3	105	22.7	99.2	105
22	24.1	104	24.1	100.0	106	24.4	101.2	105	24.0	99.6	105
29	25.1	104	25.1	99.9	106	25.2	100.3	105	25.1	99.8	105
36	26.3	104	26.2	99.9	106	26.2	100.0	104	26.3	100.1	105
43	27.3	104	27.3	99.8	106	27.2	99.7	104	27.4	100.3	105
50	28.1	104	28.2	100.5	106	28.0	99.8	104	28.3	100.8	105
57	29.3	104	29.4	100.2	106	28.9	98.5	104	29.5	100.5	105
64	30.5	104	30.2	99.1	106	29.8	97.8	104	30.7	100.5	105
71	31.7	104	31.3	98.9	106	31.2	98.3	104	32.2	101.7	105
79	32.9	104	32.6	99.0	106	32.3	98.1	104	33.4	101.6	105
86	33.6	104	33.4	99.2	106	33.0	98.0	104	34.6	102.8	105
93	34.3	94	33.8	98.5	96	33.6	98.0	94	35.3	102.8	95
121	38.6	89	38.3	99.0	91	38.3	99.1	89	39.5	102.4	90
149	42.0	89	41.4	98.6	91	42.2	100.6	89	43.2	103.0	90
177	44.3	89	44.0	99.4	91	44.6	100.7	89	45.2	102.0	90
205	46.0	89	45.8	99.6	91	46.5	101.0	89	46.4	101.0	90
233	47.3	89	46.8	99.1	91	47.1	99.6	89	47.0	99.4	90
261	47.6	89	47.5	99.8	90	47.8	100.5	89	47.7	100.3	90
289	48.2	88	48.3	100.2	90	48.5	100.5	89	48.1	99.8	90
317	48.8	88	48.7	99.7	90	49.0	100.4	89	48.7	99.8	90
345	49.4	88	49.0	99.1	90	49.4	100.1	89	49.3	99.7	90
373	50.0	87	49.9	99.9	90	50.1	100.1	89	49.7	99.4	90
401	50.4	86	50.4	99.8	90	50.7	100.5	89	50.5	100.2	90
429	50.7	85	50.8	100.1	90	51.1	100.8	89	50.8	100.1	89
457	51.1	84	51.5	100.7	90	51.4	100.5	89	51.1	100.1	89
485	51.5	84	51.9	100.8	90	51.6	100.3	89	51.6	100.3	87
513	50.5	83	51.7	102.4	90	51.5	102.0	89	51.2	101.3	86
541	49.7	83	51.2	103.0	89	50.8	102.3	89	50.5	101.7	85
569	50.4	82	51.7	102.7	88	51.5	102.3	87	50.8	101.0	85
597	50.9	81	52.4	103.0	87	52.1	102.4	84	51.4	101.1	84
625	50.7	78	52.5	103.4	86	52.1	102.7	84	50.9	100.3	83
639	49.8	78	52.5	105.5	85	51.3	103.1	83	50.3	101.0	80
653	49.0	78	52.1	106.4	85	50.9	103.8	82	49.9	101.8	79
667	49.0	76	52.3	106.6	84	51.3	104.6	80	49.9	101.7	76
681	49.2	74	51.9	105.6	84	51.1	104.0	78	49.8	101.3	75
695	48.7	71	51.4	105.5	84	50.5	103.8	76	49.3	101.2	73
709	48.5	69	51.0	105.2	84	49.5	102.0	75	48.8	100.5	72
723	48.4	67	51.0	105.5	83	48.6	100.5	73	48.3	99.9	71
Mean for Weeks											
1–13	27.3		27.1	99.6		27.0	99.4		27.4	100.5	
14–52	44.7		44.4	99.3		44.7	100.1		45.0	101.0	
53–105	49.9		51.5	103.3		50.9	102.1		50.3	100.8	

Table 14. Mean Body Weights and Survival of Female Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

	Sham Control		2.5 W/kg			5 W/kg			10 W/kg		
Day	Av. Wt. (g)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors	Av. Wt. (g)	Wt. (% of Controls)	No. of Survivors
0	17.4	105	17.4	99.7	104	17.4	100.2	105	17.5	100.4	105
8	18.4	105	18.4	100.0	104	18.5	100.5	105	18.4	100.2	105
15	19.4	105	19.6	100.7	104	19.5	100.3	105	19.3	99.0	105
22	20.2	105	20.3	100.5	104	20.2	99.7	105	20.1	99.6	105
29	20.8	105	21.0	100.8	104	20.8	99.8	105	20.7	99.6	105
36	21.5	105	21.6	100.4	103	21.5	99.9	105	21.5	99.8	105
43	22.0	105	22.0	100.0	103	21.9	99.7	105	21.8	99.4	105
50	22.5	105	22.4	99.4	103	22.3	99.0	105	22.0	97.8	105
57	22.8	105	22.7	99.8	103	22.9	100.3	105	22.6	99.1	105
64	23.3	105	23.4	100.2	103	23.4	100.4	105	23.2	99.4	105
71	23.4	105	23.7	101.2	103	23.9	102.2	105	23.8	101.6	105
79	23.9	105	24.4	101.8	103	24.7	103.1	105	24.5	102.4	105
86	24.0	105	24.1	100.5	103	24.6	102.6	105	24.5	102.2	105
93	24.3	95	24.1	99.2	93	24.9	102.4	95	24.8	102.2	95
121	26.3	90	26.4	100.2	88	26.9	102.2	90	27.0	102.5	90
149	28.8	90	29.5	102.3	88	29.9	103.9	90	30.2	104.8	90
177	30.8	90	32.2	104.6	88	32.3	105.0	90	33.0	107.1	90
205	33.4	90	35.6	106.5	88	35.1	105.2	90	35.8	107.1	90
233	36.8	90	38.2	103.7	88	38.2	103.9	89	39.1	106.3	89
261	38.4	90	40.4	105.1	88	40.8	106.1	89	42.1	109.5	89
289	40.3	90	43.6	108.1	87	43.3	107.4	89	44.1	109.4	89
317	42.3	90	45.6	108.0	87	46.0	108.9	89	46.8	110.8	89
345	45.0	90	48.0	106.7	87	48.7	108.3	89	49.0	109.0	89
373	47.6	90	50.4	105.8	87	50.7	106.4	89	51.0	107.0	89
401	49.9	90	52.2	104.5	87	52.6	105.3	89	52.7	105.6	89
429	51.4	90	53.5	104.2	87	54.3	105.8	89	53.6	104.3	89
457	53.3	89	55.2	103.7	87	55.6	104.5	89	54.8	102.9	89
485	55.0	89	56.2	102.3	87	56.8	103.3	89	56.0	102.0	88
513	54.5	87	55.9	102.6	86	56.8	104.3	87	56.7	104.1	86
541	51.9	87	54.0	104.1	86	54.7	105.4	86	54.1	104.4	85
569	52.2	83	54.2	103.8	86	55.2	105.7	85	54.5	104.5	85
597	55.3	80	56.8	102.7	85	57.5	104.0	84	56.7	102.5	84
625	56.3	76	56.9	101.1	85	57.7	102.6	84	57.1	101.5	83
639	54.8	75	55.8	101.9	83	56.2	102.5	84	55.7	101.6	82
653	54.5	71	55.3	101.4	83	55.5	101.8	82	55.7	102.1	81
667	55.1	70	55.3	100.5	82	55.1	100.1	81	55.0	99.9	81
681	54.6	70	54.6	99.9	82	54.7	100.1	80	53.9	98.6	77
695	54.0	69	54.0	99.9	80	53.6	99.1	77	53.7	99.3	73
709	53.7	68	53.2	99.1	77	53.3	99.3	76	53.2	99.0	72
723	53.0	68	52.3	98.7	75	53.4	100.7	72	52.7	99.4	72
737	52.2	67	51.3	98.3	75	53.2	101.9	69	52.2	99.9	71
Mean for Weeks											
1–13	21.5		21.6	100.4		21.7	100.6		21.5	100.0	
14–52	34.6		36.4	104.4		36.6	105.3		37.2	106.9	
53–107	53.3		54.3	101.9		54.8	102.9		54.4	102.1	

14-week Interim Evaluation

There were no changes to the hematology variables attributable to CDMA-modulated RFR exposure (Table F-2).

At the 14-week interim evaluation, mean body weights of exposed groups of males and females were similar to those of the sham controls (Table G-4). The absolute right and left kidney weights were significantly lower (7% and 8%, respectively) in 5 W/kg males, and the absolute left kidney weight was significantly lower (8%) in 10 W/kg males (Table G-4). The relative right and left kidney weights were significantly lower in 10 W/kg males. The histologic changes observed in the kidneys were not thought to be responsible for the changes in organ weights. The absolute liver weight was significantly lower (10%) in 5 W/kg males, and the relative liver weight was significantly lower in 10 W/kg males. The changes in the liver weights were considered small and sporadic and therefore not toxicologically relevant; there were no histopathologic lesions that would account for changes in liver weights. Although the absolute thymus weight of 10 W/kg males was 22% higher than that of the sham controls, the relative thymus weight was not higher in the 10 W/kg males, nor were there any histopathologic lesions in the thymus. There were no significant changes in organ weights in females.

In males, there were no exposure-related effects on reproductive organ weights, testis spermatid concentrations, caudal epididymal sperm concentrations, or sperm motility (Table H-4). In females, there were no exposure-related effects on estrous cyclicity (Table H-5, Table H-6; Figure H-2). Compared to the sham controls, there were statistically significant differences for extended estrous in the 2.5 W/kg group and extended diestrus in the 5 W/kg group; however, these changes were considered sporadic due to the lack of an exposure-related response.

In the kidney of 10 W/kg females, there was a significantly higher incidence of interstitial lymphocytic cellular infiltration (sham control, 0/10; 2.5 W/kg, 1/10, 5 W/kg, 1/10; 10 W/kg, 5/10; Table D-4). The lesions were minimal to mild in severity, and consisted of clusters of lymphocytes within the interstitium.

Pathology and Statistical Analyses

This section describes the statistically significant or biologically noteworthy changes in the incidences of malignant lymphoma and neoplasms and/or nonneoplastic lesions of the liver, pituitary gland, and uterus in the 2-year study. Summaries of the incidences of neoplasms and nonneoplastic lesions, statistical analyses of primary neoplasms that occurred with an incidence of at least 5% in at least one animal group, and historical incidences for the neoplasms mentioned in this section are presented in Appendix C for male mice and Appendix D for female mice.

Liver: There was a significantly higher incidence of hepatoblastoma in 5 W/kg males (Table 15, Table C-1, Table C-2). In 2.5 W/kg males, there was a significantly higher incidence of hepatocellular adenoma and a significantly lower incidence of hepatocellular carcinoma. When these neoplasms were combined (hepatocellular adenoma, hepatocellular carcinoma, or hepatoblastoma), there were no significant differences in the incidences between exposed and sham control groups of males. Hepatocellular adenomas were well-circumscribed lesions that compressed the surrounding liver parenchyma. Most were considerably larger than a hepatic lobule, and when located at the edge of the liver would usually cause an outward protrusion of the liver surface. They were made up of hepatocytes that lacked the normal architectural

arrangement; while portal areas might be found near the edge of a hepatocellular adenoma, they were typically lacking within the center of the neoplasm. Most adenomas lacked cellular pleomorphism and contained few, if any, mitotic figures. Hepatocellular carcinomas were usually large lesions, typically larger than hepatocellular adenomas, and frequently contained areas of necrosis. They were often multinodular and compressive, and were composed of trabeculae of neoplastic hepatocytes that were arranged at least three cells wide (in contrast to normal hepatic trabeculae, which are a single hepatocyte wide). Cells within hepatocellular carcinomas had higher mitotic rates and more pleomorphism when compared to hepatocellular adenomas. Hepatoblastomas were composed of small cells with scant cytoplasm and hyperchromatic, oval nuclei, often arranged in nests and whorls. Hepatoblastomas frequently arose from within a hepatocellular adenoma or carcinoma; when this occurred, only the hepatoblastoma was recorded.

Table 15. Incidences of Neoplasms of the Liver in Male Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Number Examined Microscopically	90	89	90	90
Hepatocellular Adenoma[a]				
Overall rate[b]	52/90 (58%)	66/89 (74%)	55/90 (61%)	62/90 (69%)
Adjusted rate[c]	62.3%	75.4%	64.9%	72.7%
Terminal rate[d]	45/66 (68%)	64/83 (77%)	51/71 (72%)	54/71 (76%)
First incidence (days)	393	625	656	478
Poly-3 test[e]	P = 0.199	P = 0.043	P = 0.428	P = 0.096
Hepatocellular Carcinoma[f]				
Overall rate	28/90 (31%)	18/89 (20%)	25/90 (28%)	31/90 (34%)
Adjusted rate	34.2%	20.6%	29.0%	36.2%
Terminal rate	18/66 (27%)	16/83 (19%)	18/71 (25%)	22/71 (31%)
First incidence (days)	608	629	559	461
Poly-3 test	P = 0.177	P = 0.033N	P = 0.287N	P = 0.459
Hepatoblastoma, Multiple[g]	0	0	1	0
Hepatoblastoma (includes multiple)[h]				
Overall rate	6/90 (7%)	6/89 (7%)	16/90 (18%)	7/90 (8%)
Adjusted rate	7.5%	6.9%	18.9%	8.5%
Terminal rate	5/66 (8%)	6/83 (7%)	14/71 (20%)	7/71 (10%)
First incidence (days)	711	729 (T)	679	729 (T)
Poly-3 test	P = 0.328	P = 0.562N	P = 0.026	P = 0.523
Hepatocellular Adenoma, Hepatocellular Carcinoma, or Hepatoblastoma[i]				
Overall rate	68/90 (76%)	70/89 (79%)	69/90 (77%)	75/90 (83%)
Adjusted rate	80.3%	79.6%	79.8%	85.6%
Terminal rate	52/66 (79%)	67/83 (81%)	59/71 (83%)	61/71 (86%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
First incidence (days)	393	625	559	461
Poly-3 test	P = 0.175	P = 0.532N	P = 0.548N	P = 0.230

T = terminal euthanasia.
[a]Historical control incidence for 2-year studies (all studies except RFR) (mean ± standard deviation): 256/499 (51.3% ± 10.7%), range 34%–70%.
[b]Number of animals with neoplasm per number of animals with liver examined microscopically.
[c]Poly-3 estimated neoplasm incidence after adjustment for intercurrent mortality.
[d]Observed incidence at terminal euthanasia.
[e]Beneath the sham control incidence is the P value associated with the trend test. Beneath the exposed group incidence are the P values corresponding to pairwise comparisons between the sham controls and that exposed group. The Poly-3 test accounts for differential mortality in animals that do not reach terminal euthanasia. A lower incidence in an exposure group is indicated by **N**.
[f]Historical control incidence: 136/499 (27.2% ± 8.6%), range 16%–42%.
[g]Number of animals with neoplasm.
[h]Historical control incidence: 13/499 (2.6% ± 1.9%), range 0%–6%.
[i]Historical control incidence: 340/499 (68.1% ± 8.7%), range 53%–80%.

Malignant Lymphoma: Compared to the sham controls, the incidences of malignant lymphoma were higher in all exposed groups of females, and the increase in the 2.5 W/kg group was statistically significant (Table 16, Table D-1, Table D-2). This was similar to the pattern seen in females exposed to GSM-modulated RFR in that the incidences of malignant lymphoma in groups exposed to RFR (either CDMA or GSM) were similar, and increasingly higher exposures did not have increasingly higher incidences. The incidence in the sham control group, shared by the GSM- and CDMA-modulated RFR studies, was at the low end of the range for malignant lymphoma in historical controls (Table 16, Table D-3). Malignant lymphoma in the CDMA-modulated RFR-exposed groups was similar in appearance, and in the organs that were involved, to that observed in the sham controls and the GSM-modulated RFR-exposed groups.

Other Tissues: Several tissues had significantly increased incidences of lesions in one, or even two, exposed groups of males or females. Some of these lesions are common background lesions and were not considered toxicologically important; the incidences of others lacked a dose response and were considered sporadic occurrences and not related to treatment.

Table 16. Incidences of Malignant Lymphoma in Female Mice Exposed to CDMA-Modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Malignant Lymphoma[a]				
Overall rate[b]	2/90 (2%)	9/89 (10%)	6/90 (7%)	7/90 (8%)
Adjusted rate[c]	2.5%	10.7%	7.2%	8.4%
Terminal rate[d]	1/67 (2%)	8/74 (11%)	4/69 (6%)	4/71 (6%)
First incidence (days)	604	689	716	635
Poly-3 test[e]	P = 0.220	P = 0.035	P = 0.152	P = 0.094

[a]Historical control incidence for 2-year studies (all studies except RFR) (mean ± standard deviation): 87/500 (17.4% ± 7.2%), range 10%–36%.
[b]Number of animals with neoplasm per number of animals necropsied.
[c]Poly-3 estimated neoplasm incidence after adjustment for intercurrent mortality.
[d]Observed incidence at terminal euthanasia.
[e]Beneath the sham control incidence is the P value associated with the trend test. Beneath the exposed group incidence are the P values corresponding to pairwise comparisons between the sham controls and that exposed group. The Poly-3 test accounts for differential mortality in animals that do not reach terminal euthanasia.

In 5 W/kg males, two adenomas (0/86, 0/84, 2/89, 0/83) and one carcinoma (0/86, 0/84, 1/89, 0/83) occurred in the pars distalis of the pituitary gland (Table C-1); no neoplasms of the pituitary gland pars distalis occurred in the sham control group or in the other exposed groups of males, including those in the GSM study (Table A-1). Only two adenomas of the pituitary gland (pars distalis) have been recorded in the current (August 2017) historical control database of 490 male mice (all studies except RFR), and no carcinomas of the pars distalis have been recorded in male mice.

In the uterus of female mice, there were one or two occurrences of adenocarcinoma (sham control, 0/89; 2.5 W/kg, 2/89; 5 W/kg, 0/88; 10 W/kg, 1/90) or leiomyosarcoma (0/89, 1/89, 1/88, 2/90) in most of the exposed groups; these neoplasms did not occur in the sham control group (Table D-1). Neither uterine adenocarcinomas nor leiomyosarcomas have been recorded in the current historical control database (0/590). These neoplasms were considered sporadic occurrences, and not related to exposure.

Genetic Toxicology

Twenty tissue samples obtained from animals in the 14-week interim evaluation study were evaluated for DNA damage using the comet assay (two sexes, two RFR modulations, five tissues). Results are based on the standard 100-cell scoring approach in use at the time these data were collected; data obtained using a 150-cell scoring approach, recommended in a recently adopted international guideline for the in vivo comet assay, are noted here for the few instances where results differed between the two methods. The complete 100-cell and 150-cell data are presented in Appendix E data tables. Significant increases in DNA damage (percent tail DNA) were observed in cells of the frontal cortex of male mice exposed to both modulations, CDMA and GSM (Table E-1, Table E-2). Positive results were also obtained for male mouse frontal cortex (CDMA and GSM) (Table E-3) using the 150-cell approach. Of note is the low percent comet tail DNA value in the frontal cortex of sham control mice. There is no appropriate historical control database to provide context for this response, but bonafide changes in DNA damage levels in a treatment group should remain constant relative the control value. No technical aspects of the study that may have influenced this control value independently of the treated group values (e.g., % agarose gel, duration of electrophoresis, electromagnetic field strength, slide position in the electrophoresis tank) were identified. Technical factors that influence control levels have not been shown to alter sensitivity to detect effects in treated groups[193]. No other tissues showed evidence of a treatment-related effect in male mice. In female mice exposed to the CDMA modulation, significant increases in DNA damage were seen in blood leukocytes using both scoring approaches (Table E-4, Table E-6). In female mouse liver samples exposed to either modulation, the mean percent comet tail DNA was elevated above the sham control for all exposures when evaluated using either scoring approach. Results of the 100-cell scoring approach were judged to be negative (Table E-4, Table E-5); scoring 150 cells resulted in a negative call for GSM-exposed female mice (Table E-6) but in CDMA-exposed female mouse liver, significant increases ($P = 0.009$) in percent comet tail DNA were seen in the 5 and 10 W/kg groups, resulting in a positive call for this dataset.

In the micronucleus assay for male mice exposed to CDMA (Table E-7), although a significant trend was observed for micronucleated polychromatic erythrocytes (PCEs) ($P = 0.013$), the absolute increase was quite small and fell within the laboratory's historical control range. In addition, no corresponding increase in micronucleated normochromatic erythrocytes was

observed; the mature erythrocyte population ought to be in steady state equilibrium after continuous 14 weeks of exposure, such as occurred in this study. Thus, the overall result in the micronucleus assay for male mice exposed to CDMA was judged to be negative. No other significant effects on either micronucleus frequency or % PCEs were seen in male or female mice exposed to either modulation of RFR.

Discussion

The Food and Drug Administration (FDA) nominated the radio frequency radiation (RFR) emissions of wireless communication devices for toxicology and carcinogenicity testing based on several factors. Current exposure guidelines are based on protection from acute injury from thermal effects, and little is known about the potential for health effects of long-term exposure. Epidemiology and toxicology studies have not definitively demonstrated an association between cell phone RFR exposure and any specific health problems in humans; however, the results of these studies are mixed and further complicated by confounding factors (including potential recall biases of the study participants that could impact the assessment of exposure). For epidemiology studies, exposures in the general population may not have occurred for a long enough period of time to accommodate the long latency period for some types of cancers in humans. Studies in laboratory animals have been complicated by limitations that researchers have faced in conducting robust studies designed to characterize the toxicity and carcinogenicity of RFR used by cell phones.

To improve on the existing methods of exposing laboratory animals to RFR, NTP worked in collaboration with experts from the Radio-Frequency Fields Group at the National Institute of Standards and Technology (NIST, Boulder, CO), IT'IS Foundation (Zurich, Switzerland), and IIT Research Institute (Chicago, IL) to design, construct, and validate a novel system of delivering RFR exposure that improved on the designs of previous exposure systems. Together with NIST and the IT'IS Foundation, NTP identified and constructed an exposure system designed to uniformly expose unrestrained, individually housed animals to a uniform field of RFR at frequencies and modulations that reflect those currently in use in wireless communication devices (GSM and CDMA). The exposure facility was installed at IIT Research Institute where all animal studies were conducted following system testing and RFR exposure validation.

Studies were designed to evaluate the toxicology and carcinogenicity of whole-body exposure to cell phone RFR in individually housed, unrestrained animals. Studies for both GSM- and CDMA-modulated RFR were conducted simultaneously with a common control group in a sham chamber. Exposures were conducted in 10-minute periods, followed by 10 minutes of rest with no RFR exposure. The exposure system ran continuously, alternating each 10 minute block of active exposure between the GSM- and CDMA-exposed mice over the course of approximately 18 hours a day, 7 days per week. Based on the on/off cycling scheme, the actual daily exposure time to RFR was approximately 9 hours per day.

Studies were conducted in multiple phases. The first phase comprised a series of short-term toxicity studies conducted in young and aged B6C3F1/N mice and Hsd:Harlan Sprague Dawley® SD® rats to characterize the effects of RFR exposure on body temperature and the potential impact of animal size. The impact of RFR exposure during pregnancy was also evaluated in rats. These studies demonstrated that rats were more sensitive to the heating effects of RFR than were the mice[144]. In both young and aged male and female mice, body temperatures were only sporadically increased at exposures to RFR up to 12 W/kg (GSM and CDMA). These data suggest that exposures of up to 12 W/kg did not markedly alter the thermoregulatory capacity in mice. It must be noted, however, that core body temperature is a general surrogate for the heating

effects of RFR and that these results do not address the issue of potential changes in temperature that may occur in localized areas within some tissues.

The findings from these short-term studies were used to guide the selection of RFR exposure levels for the 28-day and 2-year studies. Because no significant effect of RFR exposure up to 12 W/kg was observed in the body temperature of mice in these thermal pilot studies, a higher level of RFR exposure (15 W/kg) was selected for the highest exposure group in the 28-day studies. The selection of 15 W/kg was determined by the technical limitations of the exposure system to deliver higher RFR fields in the 28-day studies. Results from the 28-day studies demonstrated some increases in core body temperature at various time points at 10 and 15 W/kg. Based on the observed increases in body temperature and the power limitations of the system to generate maximum RFR fields for the large numbers of mice that were required for the 2-year studies, the highest exposure level for the 2-year studies was 10 W/kg.

The effects of whole-body exposure to GSM- or CDMA-modulated cell phone RFR at 1,900 MHz for 14 weeks or 2 years were studied in B6C3F1/N mice at specific absorption rates (SARs) of 2.5, 5, and 10 W/kg, with a common sham control group for both GSM- and CDMA-modulated signals. At SAR exposures up to 10 W/kg, there were no exposure-related effects on survival or mean body weights in either modulation (GSM or CDMA).

In both the GSM and CDMA studies, the incidences of malignant lymphoma in all exposed female groups were higher than that in the sham controls. These incidences were significantly increased only in the GSM groups at 2.5 and 5 W/kg, and in the CDMA group at 2.5 W/kg compared to sham controls. The 2% incidence of lymphoma in the concurrent sham controls was the lowest incidence observed thus far in female B6C3F1/N mice. The incidence is well below the overall historical control mean of 16%, and appreciably lower than the lower end of the range of overall historical control values in other studies (10% to 36%). Additionally, the incidences of malignant lymphoma in all exposed groups were within the range observed in overall historical controls. These considerations reduce the confidence that these increases in incidences were attributable to the RFR exposure, so these were considered equivocal findings. In NTP conclusions, such uncertain responses in the absence of other clearer effects on carcinogenicity would be referred to as equivocal evidence of carcinogenicity (i.e., may have been related to exposure).

In males, there were no common lesions observed between the two modulations. Potential RFR-mediated effects observed in the lung and the skin of males were specific to the GSM modulation. In the lung, there was a positive trend in the combined incidence of alveolar/bronchiolar adenoma or carcinoma in male mice, but there was no significant effect in any of the individual groups compared to the sham controls. The combined incidences at the upper two exposure levels exceeded the historical control range (16% to 34%). Despite a significant trend in the combined incidence of alveolar/bronchiolar adenoma or carcinoma, the observation that the incidences were only marginally outside the historical range, and the fact that the incidences of focal alveolar epithelial hyperplasia, a potential preneoplastic lesion, were similar in all dose groups, reduces the confidence that the increased incidences were attributable to the RFR exposure. Therefore, these were considered equivocal findings.

The combined incidences of fibrosarcoma, sarcoma, or malignant fibrous histiocytoma in the skin were higher in the 5 and 10 W/kg GSM males but were not statistically different than that of

the sham controls. Malignant fibrous histiocytoma was the predominant neoplasm in this combination. There was also a lack of an increased exposure level response. However, the incidences in both groups were above the historical control range for malignant fibrous histiocytoma. Additionally, there was one occurrence of a sarcoma in the 2.5 W/kg GSM males and one occurrence of a fibrosarcoma in the 10 W/kg GSM males. While the incidences in the 5 and 10 W/kg GSM males were not significant versus the current sham controls, the increases were seen in the top two exposure groups and were outside the historical range. None of the malignant fibrous histiocytomas in these groups showed evidence of metastasis, and most of the neoplasms were restricted to single occurrences on the tail. The increases in incidences observed may have been attributable to the RFR exposure, so these were considered equivocal findings.

At 2 years in the CDMA study only, there was a significantly increased incidence of hepatoblastoma in males exposed to 5 W/kg. The incidence at 5 W/kg exceeded the historical control; however, no increases were observed in males at 10 W/kg. Additionally, when all liver neoplasms (hepatocellular adenoma, hepatocellular carcinoma, or hepatoblastoma) were combined, there were no significant differences between any of the exposed groups compared to the sham controls. The isolated increase in only the 5 W/kg group and overall lack of exposure response reduces the confidence that the increase in incidence of hepatoblastoma observed was attributable to the RFR exposure, therefore, this was considered an equivocal finding.

Subsets of male and female mice from the 2-year studies were examined at 14 weeks to evaluate biomarkers of genotoxicity. Chromosomal damage was evaluated using the peripheral blood erythrocyte micronucleus (MN) assay, and DNA damage was evaluated in the frontal cortex, hippocampus, cerebellum, liver, and peripheral blood using the comet assay. Results of the MN assays were negative, but significantly higher levels of DNA damage were observed in cells of the frontal cortex of male mice exposed to both modulations (GSM and CDMA) and in blood leukocytes of female mice (CDMA only).

Unlike ionizing radiation or ultraviolet radiation, RFR is not sufficiently energetic, by several orders of magnitude, to directly damage macromolecules[4], and little is known about the mechanisms by which RFR could induce DNA damage in the absence of thermal effects. Proposed mechanisms include, for example, induction of oxygen radicals and interference with DNA repair mechanisms[53; 194].

No histopathologic assessments of cytotoxicity (apoptosis and necrosis) were conducted in the male mouse brain tissues that were examined for DNA damage, which leaves open the possibility that apoptosis or necrosis may have confounded the comet assay results. However, this seems unlikely as brain sections from other groups of mice in this interim 14-week study and in the 2-year study did undergo histopathologic assessment and no significant evidence of cytotoxicity was observed.

Although increases in DNA damage were observed in the frontal cortex of male mice, there were no increases observed in the incidences of any type of neoplasm in the brain of males in the 2-year study. Similarly, while increased DNA damage was observed in blood leukocytes of female mice exposed to CDMA-modulated cell phone RFR, there were no increased incidences of related neoplasms. Therefore, no association was established between DNA damage appearing early in the studies and neoplasm development in these tissues.

Conclusions

Under the conditions of these 2-year studies, there was *equivocal evidence of carcinogenic*[l] *activity* of GSM-modulated cell phone RFR at 1,900 MHz in male B6C3F1/N mice based on the combined incidences of fibrosarcoma, sarcoma, or malignant fibrous histiocytoma in the skin and the incidences of alveolar/bronchiolar adenoma or carcinoma (combined) in the lung. There was *equivocal evidence of carcinogenic activity* of GSM-modulated cell phone RFR at 1,900 MHz in female B6C3F1/N mice based on the incidences of malignant lymphoma (all organs). There was *equivocal evidence of carcinogenic activity* of CDMA-modulated cell phone RFR at 1,900 MHz in male B6C3F1/N mice based on the incidences of hepatoblastoma of the liver. There was *equivocal evidence of carcinogenic activity* of CDMA-modulated cell phone RFR at 1,900 MHz in female B6C3F1/N mice based on the incidences of malignant lymphoma (all organs).

Exposure to GSM- or CDMA-modulated cell phone RFR at 1,900 MHz did not increase the incidence of any nonneoplastic lesions in male or female B6C3F1/N mice.

[l]See Explanation of Levels of Evidence of Carcinogenic Activity. A summary of the Peer Review Panel comments and the public discussion on this Technical Report appears in Appendix L.

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Appendix A. Summary of Lesions in Male Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

Tables

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Table A-1. Summary of the Incidence of Neoplasms in Male Mice Exposed to GSM-modulated Cell Phone RFR for Two Years[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Disposition Summary				
Animals initially in study	105	105	105	105
14-week interim evaluation	15	15	15	15
Early deaths				
Accidental death	–	1	–	–
Moribund	8	6	2	6
Natural deaths	16	19	8	12
Survivors				
Died last week of study	–	–	1	4
Terminal euthanasia	66	63	79	68
Missing	–	1	–	–
Animals examined microscopically	100	100	100	100
14-week Interim Evaluation				
Nervous System				
Brain	(10)	(10)	(10)	(10)
Hamartoma, lipomatous	–	–	–	1 (10%)
Systems Examined with No Neoplasms Observed				
Alimentary System				
Cardiovascular System				
Endocrine System				
General Body System				
Genital System				
Hematopoietic System				
Integumentary System				
Musculoskeletal System				
Respiratory System				
Special Senses System				
Urinary System				
Two-year Study				
Alimentary System				
Esophagus	(88)	(87)	(88)	(90)
Gallbladder	(73)	(66)	(74)	(79)
Intestine large, cecum	(81)	(77)	(84)	(78)
Leiomyoma	–	–	1 (1%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Intestine large, colon	(84)	(83)	(85)	(84)
Intestine large, rectum	(84)	(85)	(86)	(84)
Intestine small, duodenum	(77)	(77)	(83)	(79)
Adenocarcinoma	1 (1%)	1 (1%)	–	–
Adenoma	–	–	1 (1%)	–
Intestine small, ileum	(81)	(79)	(85)	(80)
Intestine small, jejunum	(79)	(79)	(82)	(79)
Adenocarcinoma	2 (3%)	–	–	1 (1%)
Hepatocellular carcinoma, metastatic, liver	1 (1%)	–	–	–
Hepatocholangiocarcinoma, metastatic, liver	–	1 (1%)	–	–
Liver	(90)	(89)	(90)	(90)
Adenocarcinoma, metastatic, harderian gland	–	1 (1%)	–	–
Carcinoma, metastatic, islets, pancreatic	–	–	–	1 (1%)
Hemangioma	–	–	1 (1%)	–
Hemangiosarcoma	1 (1%)	3 (3%)	2 (2%)	2 (2%)
Hepatoblastoma	6 (7%)	3 (3%)	8 (9%)	1 (1%)
Hepatoblastoma, multiple	–	–	1 (1%)	–
Hepatocellular adenoma	25 (28%)	28 (31%)	20 (22%)	26 (29%)
Hepatocellular adenoma, multiple	27 (30%)	33 (37%)	46 (51%)	29 (32%)
Hepatocellular carcinoma	26 (29%)	23 (26%)	28 (31%)	19 (21%)
Hepatocellular carcinoma, multiple	2 (2%)	2 (2%)	2 (2%)	3 (3%)
Hepatocholangiocarcinoma	1 (1%)	4 (4%)	–	–
Malignant fibrous histiocytoma, metastatic, skin	1 (1%)	–	–	–
Mesentery	(12)	(14)	(13)	(17)
Hemangiosarcoma	1 (8%)	–	1 (8%)	–
Hepatocholangiocarcinoma, metastatic, liver	–	1 (7%)	–	–
Malignant fibrous histiocytoma, metastatic, skin	1 (8%)	–	–	–
Fat, hepatocholangiocarcinoma, metastatic, liver	1 (8%)	1 (7%)	–	–
Fat, lipoma	1 (8%)	–	–	–
Pancreas	(87)	(88)	(88)	(86)
Hepatocholangiocarcinoma, metastatic, liver	1 (1%)	2 (2%)	–	–
Salivary glands	(90)	(89)	(89)	(89)
Stomach, forestomach	(88)	(87)	(89)	(87)
Squamous cell papilloma	–	1 (1%)	2 (2%)	
Stomach, glandular	(87)	(86)	(88)	(85)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Malignant fibrous histiocytoma, metastatic, skin	1 (1%)	–	–	–
Tooth	(27)	(26)	(16)	(20)
Cardiovascular System				
Aorta	(89)	(89)	(89)	(87)
Alveolar/bronchiolar carcinoma, metastatic, lung	1 (1%)	–	–	–
Hepatocholangiocarcinoma, metastatic, liver	–	1 (1%)	–	–
Blood vessel	(1)	(0)	(0)	(0)
Heart	(90)	(89)	(90)	(90)
Alveolar/bronchiolar carcinoma, metastatic, lung	1 (1%)	1 (1%)	–	2 (2%)
Hemangiosarcoma	–	1 (1%)	–	1 (1%)
Hepatocholangiocarcinoma, metastatic, liver	1 (1%)	2 (2%)	–	–
Endocrine System				
Adrenal cortex	(90)	(89)	(89)	(88)
Bilateral, malignant fibrous histiocytoma, metastatic, skin	1 (1%)	–	–	–
Subcapsular, adenoma	–	3 (3%)	3 (3%)	–
Adrenal medulla	(90)	(88)	(88)	(86)
Islets, pancreatic	(88)	(88)	(90)	(89)
Adenoma	–	–	–	2 (2%)
Adenoma, multiple	–	1 (1%)	–	–
Carcinoma	–	–	1 (1%)	1 (1%)
Parathyroid gland	(68)	(68)	(67)	(66)
Pituitary gland	(86)	(85)	(87)	(85)
Thyroid gland	(89)	(88)	(88)	(88)
General Body System				
Peritoneum	(1)	(0)	(0)	(0)
Hepatocholangiocarcinoma, metastatic, liver	1 (100%)	–	–	–
Tissue NOS	(0)	(0)	(0)	(1)
Genital System				
Coagulating gland	(2)	(2)	(0)	(4)
Epididymis	(90)	(89)	(90)	(90)
Hemangioma	–	1 (1%)	–	–
Hepatocholangiocarcinoma, metastatic, liver	–	1 (1%)	–	–
Preputial gland	(89)	(88)	(90)	(89)
Prostate	(90)	(87)	(90)	(87)
Seminal vesicle	(90)	(88)	(90)	(90)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Fibroma	1 (1%)	–	–	–
Malignant fibrous histiocytoma, metastatic, skin	1 (1%)	–	–	–
Testis	(90)	(88)	(90)	(90)
Hemangioma	–	1 (1%)	–	–
Interstitial cell, adenoma	2 (2%)	–	–	–
Hematopoietic System				
Bone marrow	(90)	(88)	(90)	(90)
Hemangiosarcoma	–	–	1 (1%)	1 (1%)
Lymph node	(6)	(8)	(7)	(9)
Sarcoma, metastatic, skin	–	1 (13%)	–	–
Axillary, hepatocholangiocarcinoma, metastatic, liver	1 (17%)	–	–	–
Lymph node, mandibular	(72)	(61)	(63)	(60)
Lymph node, mesenteric	(85)	(82)	(88)	(83)
Hemangioma	1 (1%)	–	–	–
Hepatocholangiocarcinoma, metastatic, liver	–	1 (1%)	–	–
Malignant fibrous histiocytoma, metastatic, skin	1 (1%)	–	–	–
Spleen	(87)	(88)	(89)	(88)
Hemangiosarcoma	–	4 (5%)	1 (1%)	1 (1%)
Thymus	(75)	(83)	(81)	(72)
Hepatocellular carcinoma, metastatic, liver	–	1 (1%)	–	–
Hepatocholangiocarcinoma, metastatic, liver	–	3 (4%)	–	–
Thymoma benign	–	–	1 (1%)	–
Integumentary System				
Mammary gland	(2)	(5)	(2)	(8)
Skin	(90)	(89)	(90)	(90)
Keratoacanthoma	–	–	1 (1%)	–
Pilomatrixoma	1 (1%)	–	–	–
Sebaceous gland, adenoma	–	–	1 (1%)	–
Subcutaneous tissue, fibrosarcoma	–	–	–	1 (1%)
Subcutaneous tissue, hemangioma	–	–	–	1 (1%)
Subcutaneous tissue, hemangiosarcoma	1 (1%)	–	2 (2%)	–
Subcutaneous tissue, lipoma	1 (1%)	–	–	–
Subcutaneous tissue, liposarcoma		1 (1%)	–	–
Subcutaneous tissue, malignant fibrous histiocytoma	1 (1%)	–	4 (4%)	3 (3%)
Subcutaneous tissue, malignant fibrous histiocytoma, multiple	–	–	1 (1%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Subcutaneous tissue, sarcoma	–	1 (1%)	–	–
Musculoskeletal System				
Bone	(90)	(88)	(90)	(90)
Hepatocholangiocarcinoma, metastatic, liver	–	1 (1%)	–	–
Skeletal muscle	(90)	(89)	(90)	(90)
Hepatocellular carcinoma, metastatic, liver	1 (1%)	–	1 (1%)	–
Hepatocholangiocarcinoma, metastatic, liver	1 (1%)	2 (2%)	–	–
Malignant fibrous histiocytoma, metastatic, skin	1 (1%)	–	–	–
Sarcoma	1 (1%)	–	–	–
Nervous System				
Brain	(90)	(89)	(90)	(90)
Hepatocholangiocarcinoma, metastatic, liver	1 (1%)	–	–	–
Brain trigeminal ganglion	(69)	(79)	(72)	(79)
Nerve trigeminal	(67)	(53)	(66)	(63)
Peripheral nerve, sciatic	(89)	(89)	(90)	(89)
Spinal cord	(90)	(89)	(90)	(90)
Respiratory System				
Lung	(90)	(89)	(90)	(90)
Adenocarcinoma, metastatic, Harderian gland	–	1 (1%)	–	–
Alveolar/bronchiolar adenoma	11 (12%)	13 (15%)	16 (18%)	15 (17%)
Alveolar/bronchiolar adenoma, multiple	2 (2%)	–	2 (2%)	1 (1%)
Alveolar/bronchiolar carcinoma	11 (12%)	12 (13%)	15 (17%)	17 (19%)
Alveolar/bronchiolar carcinoma, multiple	2 (2%)	–	1 (1%)	1 (1%)
Carcinoma, metastatic, islets, pancreatic	–	–	–	1 (1%)
Hepatoblastoma, metastatic, liver	1 (1%)	1 (1%)	–	1 (1%)
Hepatocellular carcinoma, metastatic, liver	11 (12%)	8 (9%)	6 (7%)	5 (6%)
Hepatocholangiocarcinoma, metastatic, liver	1 (1%)	3 (3%)	–	–
Sarcoma, metastatic, skin	–	1 (1%)	–	–
Mediastinum	(0)	(0)	(2)	(1)
Alveolar/bronchiolar carcinoma, metastatic, lung	–	–	–	1 (100%)
Hibernoma	–	–	2 (100%)	–
Nose	(90)	(89)	(90)	(89)
Trachea	(90)	(89)	(89)	(90)
Special Senses System				
Eye	(90)	(89)	(90)	(90)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Adenocarcinoma, metastatic, Harderian gland	–	1 (1%)	–	–
Harderian gland	(88)	(89)	(90)	(90)
Adenocarcinoma	3 (3%)	2 (2%)	1 (1%)	–
Adenoma	6 (7%)	7 (8%)	11 (12%)	5 (6%)
Urinary System				
Kidney	(90)	(89)	(90)	(89)
Alveolar/bronchiolar carcinoma, metastatic, lung		–	–	1 (1%)
Hepatocellular carcinoma, metastatic, liver	1 (1%)	–	–	–
Hepatocholangiocarcinoma, metastatic, liver	1 (1%)	2 (2%)	–	–
Malignant fibrous histiocytoma, metastatic, skin	1 (1%)	–	–	–
Renal tubule, adenoma	–	1 (1%)	1 (1%)	–
Urinary bladder	(87)	(88)	(90)	(89)
Hemangioma	–	2 (2%)	–	–
Urothelium, papilloma	–	–	–	2 (2%)
Systemic Lesions				
Multiple organs[b]	(90)	(89)	(90)	(90)
Histiocytic sarcoma	–	–	1 (1%)	2 (2%)
Leukemia granulocytic	–	–	–	1 (1%)
Lymphoma malignant	6 (7%)	4 (4%)	3 (3%)	4 (4%)
Mast cell tumor	1 (1%)	–	–	–
Neoplasm Summary				
Total animals with primary neoplasms[c]				
14-week interim evaluation	–	–	–	1
Two-year study	79	82	82	77
Total primary neoplasms				
14-week interim evaluation	–	–	–	1
Two-year study	144	152	182	140
Total animals with benign neoplasms				
14-week interim evaluation	–	–	–	1
Two-year study	61	67	77	61
Total benign neoplasms				
14-week interim evaluation	–	–	–	1
Two-year study	77	91	109	81
Total animals with malignant neoplasms				
Two-year study	49	47	53	45

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Total malignant neoplasms				
Two-year study	66	61	73	59
Total animals with metastatic neoplasms				
Two-year study	14	15	6	10
Total metastatic neoplasms				
Two-year study	34	37	7	12
Total animals with uncertain neoplasms-benign or malignant				
Two-year study	1	–	–	–
Total uncertain neoplasms				
Two-year study	1	–	–	–

[a]Number of animals examined microscopically at the site and the number of animals with neoplasm.
[b]Number of animals with any tissue examined microscopically.
[c]Primary neoplasms: all neoplasms except metastatic neoplasms.

Table A-2. Statistical Analysis of Primary Neoplasms in Male Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Harderian Gland: Adenoma				
Overall rate[a]	6/90 (7%)	7/89 (8%)	11/90 (12%)	5/90 (6%)
Adjusted rate[b]	7.5%	8.7%	12.7%	6.0%
Terminal rate[c]	6/66 (9%)	5/63 (8%)	11/80 (14%)	4/72 (6%)
First incidence (days)	729 (T)	672	729 (T)	689
Poly-3 test[d]	P = 0.415N	P = 0.506	P = 0.194	P = 0.470N
Harderian Gland: Adenoma or Carcinoma				
Overall rate	9/90 (10%)	9/89 (10%)	12/90 (13%)	5/90 (6%)
Adjusted rate	11.2%	11.1%	13.9%	6.0%
Terminal rate	8/66 (12%)	5/63 (8%)	12/80 (15%)	4/72 (6%)
First incidence (days)	690	651	729 (T)	689
Poly-3 test	P = 0.160N	P = 0.588N	P = 0.386	P = 0.179N
Liver: Hepatocellular Adenoma				
Overall rate	52/90 (58%)	61/89 (69%)	66/90 (73%)	55/90 (61%)
Adjusted rate	62.3%	73.8%	75.3%	64.7%
Terminal rate	45/66 (68%)	52/63 (83%)	61/80 (76%)	49/72 (68%)
First incidence (days)	393	533	605	614
Poly-3 test	P = 0.526N	P = 0.072	P = 0.044	P = 0.437
Liver: Hepatocellular Carcinoma				
Overall rate	28/90 (31%)	25/89 (28%)	30/90 (33%)	22/90 (24%)
Adjusted rate	34.2%	30.0%	34.1%	25.9%
Terminal rate	18/66 (27%)	15/63 (24%)	25/80 (31%)	17/72 (24%)
First incidence (days)	608	547	604	538
Poly-3 test	P = 0.169N	P = 0.340N	P = 0.556N	P = 0.157N
Liver: Hepatocellular Adenoma or Carcinoma				
Overall rate	67/90 (74%)	68/89 (76%)	74/90 (82%)	64/90 (71%)
Adjusted rate	79.1%	79.9%	83.4%	74.3%
Terminal rate	51/66 (77%)	52/63 (83%)	66/80 (83%)	54/72 (75%)
First incidence (days)	393	533	604	538
Poly-3 test	P = 0.232N	P = 0.526	P = 0.296	P = 0.281N
Liver: Hepatoblastoma				
Overall rate	6/90 (7%)	3/89 (3%)	9/90 (10%)	1/90 (1%)
Adjusted rate	7.5%	3.7%	10.4%	1.2%
Terminal rate	5/66 (8%)	3/63 (5%)	8/80 (10%)	1/72 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
First incidence (days)	711	729 (T)	667	729 (T)
Poly-3 test	P = 0.105N	P = 0.244N	P = 0.350	P = 0.054N
Liver: Hepatocellular Carcinoma or Hepatoblastoma				
Overall rate	32/90 (36%)	27/89 (30%)	35/90 (39%)	23/90 (26%)
Adjusted rate	39.1%	32.4%	39.7%	27.1%
Terminal rate	22/66 (33%)	17/63 (27%)	29/80 (36%)	18/72 (25%)
First incidence (days)	608	547	604	538
Poly-3 test	P = 0.089N	P = 0.230N	P = 0.534	P = 0.067N
Liver: Hepatocellular Adenoma, Hepatocellular Carcinoma, or Hepatoblastoma				
Overall rate	68/90 (76%)	68/89 (76%)	74/90 (82%)	65/90 (72%)
Adjusted rate	80.3%	79.9%	83.4%	75.4%
Terminal rate	52/66 (79%)	52/63 (83%)	66/80 (83%)	55/72 (76%)
First incidence (days)	393	533	604	538
Poly-3 test	P = 0.243N	P = 0.553N	P = 0.367	P = 0.276N
Lung: Alveolar/bronchiolar Adenoma				
Overall rate	13/90 (14%)	13/89 (15%)	18/90 (20%)	16/90 (18%)
Adjusted rate	16.0%	16.0%	20.7%	19.0%
Terminal rate	9/66 (14%)	10/63 (16%)	16/80 (20%)	14/72 (19%)
First incidence (days)	488	663	604	658
Poly-3 test	P = 0.297	P = 0.583	P = 0.279	P = 0.380
Lung: Alveolar/bronchiolar Carcinoma				
Overall rate	13/90 (14%)	12/89 (13%)	16/90 (18%)	18/90 (20%)
Adjusted rate	16.1%	14.7%	18.5%	21.2%
Terminal rate	12/66 (18%)	8/63 (13%)	16/80 (20%)	14/72 (19%)
First incidence (days)	568	594	729 (T)	614
Poly-3 test	P = 0.165	P = 0.488N	P = 0.418	P = 0.259
Lung: Alveolar/bronchiolar Adenoma or Carcinoma				
Overall rate	23/90 (26%)	24/89 (27%)	32/90 (36%)	34/90 (38%)
Adjusted rate	28.1%	29.2%	36.8%	39.9%
Terminal rate	18/66 (27%)	17/63 (27%)	30/80 (38%)	28/72 (39%)
First incidence (days)	488	594	604	614
Poly-3 test	P = 0.040	P = 0.506	P = 0.149	P = 0.074
Skin (Subcutaneous Tissue): Malignant Fibrous Histiocytoma				
Overall rate	1/90 (1%)	0/89 (0%)	5/90 (6%)	3/90 (3%)
Adjusted rate	1.2%	0.0%	5.8%	3.6%
Terminal rate	0/66 (0%)	0/63 (0%)	4/80 (5%)	3/72 (4%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
First incidence (days)	674	–[e]	654	729 (T)
Poly-3 test	P = 0.127	P = 0.499N	P = 0.124	P = 0.321
Skin (Subcutaneous Tissue): Fibrosarcoma, Sarcoma, or Malignant Fibrous Histiocytoma				
Overall rate	1/90 (1%)	1/89 (1%)	5/90 (6%)	4/90 (4%)
Adjusted rate	1.2%	1.2%	5.8%	4.7%
Terminal rate	0/66 (0%)	0/63 (0%)	4/80 (5%)	3/72 (4%)
First incidence (days)	674	523	654	488
Poly-3 test	P = 0.093	P = 0.758N	P = 0.124	P = 0.197
Spleen: Hemangiosarcoma				
Overall rate	0/87 (0%)	4/88 (5%)	1/89 (1%)	1/88 (1%)
Adjusted rate	0.0%	5.0%	1.2%	1.2%
Terminal rate	0/66 (0%)	3/63 (5%)	1/80 (1%)	0/72 (0%)
First incidence (days)	–	672	729 (T)	681
Poly-3 test	P = 0.538N	P = 0.065	P = 0.515	P = 0.507
All Organs: Hemangiosarcoma				
Overall rate	2/90 (2%)	6/89 (7%)	6/90 (7%)	2/90 (2%)
Adjusted rate	2.5%	7.4%	6.9%	2.4%
Terminal rate	0/66 (0%)	4/63 (6%)	6/80 (8%)	1/72 (1%)
First incidence (days)	702	667	729 (T)	681
Poly-3 test	P = 0.394N	P = 0.141	P = 0.163	P = 0.677N
All Organs: Hemangioma or Hemangiosarcoma				
Overall rate	3/90 (3%)	10/89 (11%)	7/90 (8%)	3/90 (3%)
Adjusted rate	3.7%	12.3%	8.1%	3.6%
Terminal rate	1/66 (2%)	8/63 (13%)	7/80 (9%)	2/72 (3%)
First incidence (days)	702	667	729 (T)	681
Poly-3 test	P = 0.277N	P = 0.042	P = 0.195	P = 0.641N
All Organs: Malignant Lymphoma				
Overall rate	6/90 (7%)	4/89 (4%)	3/90 (3%)	4/90 (4%)
Adjusted rate	7.3%	4.9%	3.5%	4.8%
Terminal rate	4/66 (6%)	1/63 (2%)	3/80 (4%)	3/72 (4%)
First incidence (days)	263	609	729 (T)	690
Poly-3 test	P = 0.307N	P = 0.375N	P = 0.222N	P = 0.359N
All Organs: Benign Neoplasms				
Overall rate	61/90 (68%)	67/89 (75%)	77/90 (86%)	61/90 (68%)
Adjusted rate	72.4%	80.8%	87.4%	71.4%
Terminal rate	51/66 (77%)	53/63 (89%)	71/80 (89%)	53/72 (74%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
First incidence (days)	393	533	604	614
Poly-3 test	P = 0.386N	P = 0.126	P = 0.009	P = 0.510N
All Organs: Malignant Neoplasms				
Overall rate	49/90 (54%)	47/89 (53%)	53/90 (59%)	45/90 (50%)
Adjusted rate	57.6%	54.1%	59.8%	51.8%
Terminal rate	33/66 (50%)	27/63 (43%)	46/80 (58%)	34/72 (47%)
First incidence (days)	263	523	604	488
Poly-3 test	P = 0.291N	P = 0.379N	P = 0.443	P = 0.269N
All Organs: Benign or Malignant Neoplasms				
Overall rate	79/90 (88%)	82/89 (92%)	82/90 (91%)	77/90 (86%)
Adjusted rate	90.2%	93.7%	92.4%	87.7%
Terminal rate	59/66 (89%)	59/63 (94%)	74/80 (93%)	62/72 (86%)
First incidence (days)	263	523	604	488
Poly-3 test	P = 0.231N	P = 0.275	P = 0.398	P = 0.389N

T = terminal euthanasia.
[a]Number of neoplasm-bearing animals/number of animals examined. Denominator is number of animals examined microscopically for liver, lung, and spleen; for other tissues, denominator is number of animals necropsied.
[b]Poly-3 estimated neoplasm incidence after adjustment for intercurrent mortality.
[c]Observed incidence at terminal euthanasia.
[d]Beneath the sham control incidence is the P value associated with the trend test. Beneath the exposed group incidence are the P values corresponding to pairwise comparisons between the sham controls and that exposed group. The Poly-3 test accounts for differential mortality in animals that do not reach terminal euthanasia. A negative trend or a lower incidence in an exposure group is indicated by **N**.
[e]Not applicable; no neoplasms in animal group.

Table A-3. Historical Incidence of Skin Neoplasms in Control Male B6C3F1/N Mice[a]

Study (Study Start)	Malignant Fibrous Histiocytoma	Fibrosarcoma, Sarcoma, or Malignant Fibrous Histiocytoma
Historical Incidence: All Studies		
Antimony trioxide (October 2008)	0/50	0/50
2,3-Butanedione (August 2009)	0/50	0/50
Green tea extract (July 2007)	0/50	0/50
2-Hydroxy-4-methoxybenzophenone (July 2010)	0/49	0/49
Indole-3-carbinol (April 2007)	0/50	1/50
CIMSTAR 3800 (May 2008)	0/50	0/50
Trim VX (August 2009)	0/50	1/50
p-Chloro-α,α,α-trifluorotoluene (January 2011)	1/50	1/50
Pentabromodiphenyl ether mixture [DE-71 (technical grade)] (February 2008)	0/50	0/50
Radiofrequency radiation (June 2012)	1/90	1/90
Tetrabromobisphenol A (August 2007)	0/50	1/50
Overall Historical Incidence		
Total (%)	2/589 (0.3%)	5/589 (0.9%)
Mean ± standard deviation	0.3% ± 0.7%	0.8% ± 1.0%
Range	0%–2%	0%–2%

[a]Data as of August 2017.

Table A-4. Historical Incidence of Alveolar/bronchiolar Neoplasms in Control Male B6C3F1/N Mice[a]

Study (Study Start)	Adenoma	Carcinoma	Adenoma or Carcinoma
Historical Incidence: All Studies			
Antimony trioxide (October 2008)	10/50	4/50	13/50
2,3-Butanedione (August 2009)	5/50	5/50	9/50
Green tea extract (July 2007)	12/50	2/50	14/50
2-Hydroxy-4-methoxybenzophenone (July 2010)	7/49	5/49	11/49
Indole-3-carbinol (April 2007)	4/50	4/50	8/50
CIMSTAR 3800 (May 2008)	5/50	8/50	13/50
Trim VX (August 2009)	6/50	10/50	14/50
p-Chloro-α,α,α-trifluorotoluene (January 2011)	11/50	6/50	17/50
Pentabromodiphenyl ether mixture [DE-71 (technical grade)] (February 2008)	5/50	5/50	10/50
Radiofrequency radiation (June 2012)	13/90	13/90	23/90
Tetrabromobisphenol A (August 2007)	6/50	4/50	10/50

Study (Study Start)	Adenoma	Carcinoma	Adenoma or Carcinoma
Overall Historical Incidence			
Total (%)	84/589 (14.3%)	66/589 (11.2%)	142/589 (24.1%)
Mean ± standard deviation	14.3% ± 5.4%	11.0% ± 4.4%	24.0% ± 5.3%
Range	8%–24%	4%–20%	16%–34%

[a]Data as of August 2017.

Table A-5. Summary of the Incidence of Non-neoplastic Lesions in Male Mice Exposed to GSM-modulated Cell Phone RFR for Two Years[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Disposition Summary				
Animals initially in study	105	105	105	105
14-week interim evaluation	15	15	15	15
Early deaths				
Accidental death	–	1	–	–
Moribund	8	6	2	6
Natural deaths	16	19	8	12
Survivors				
Died last week of study	–	–	1	4
Terminal euthanasia	66	63	79	68
Missing	–	1	–	–
Animals examined microscopically	100	100	100	100
14-week Interim Evaluation				
Alimentary System				
Liver	(10)	(10)	(10)	(10)
Inflammation, focal	–	2 (20%)	4 (40%)	–
Pancreas	(10)	(10)	(10)	(10)
Infiltration cellular, lymphocyte	–	1 (10%)	–	–
Inflammation, chronic	–	1 (10%)	–	–
Genital System				
Prostate	(10)	(10)	(10)	(10)
Infiltration cellular, lymphocyte	–	–	2 (20%)	1 (10%)
Hematopoietic System				
Lymph node, mandibular	(5)	(7)	(10)	(8)
Hemorrhage	–	–	2 (20%)	–
Nervous System				
Brain	(10)	(10)	(10)	(10)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Hemorrhage	1 (10%)	1 (10%)	–	–
Respiratory System				
Lung	(10)	(10)	(10)	(10)
Congestion	1 (10%)	–	–	1 (10%)
Hemorrhage	2 (20%)	3 (30%)	2 (20%)	2 (20%)
Nose	(10)	(10)	(10)	(10)
Respiratory epithelium, hyperplasia	–	2 (20%)	1 (10%)	–
Urinary System				
Kidney	(10)	(10)	(10)	(10)
Nephropathy, chronic progressive	1 (10%)	2 (20%)	1 (10%)	–
Interstitium, infiltration cellular, lymphocyte	2 (20%)	1 (10%)	1 (10%)	1 (10%)
Systems Examined with No Lesions Observed				
Cardiovascular System				
Endocrine System				
General Body System				
Integumentary System				
Musculoskeletal System				
Special Senses System				
Two-year Study				
Alimentary System				
Esophagus	(88)	(87)	(88)	(90)
Gallbladder	(73)	(66)	(74)	(79)
Inflammation, acute	–	1 (2%)	–	–
Intestine large, cecum	(81)	(77)	(84)	(78)
Intestine large, colon	(84)	(83)	(85)	(84)
Intestine large, rectum	(84)	(85)	(86)	(84)
Intestine small, duodenum	(77)	(77)	(83)	(79)
Intestine small, ileum	(81)	(79)	(85)	(80)
Peyer’s patch, hyperplasia, lymphoid	1 (1%)	1 (1%)	1 (1%)	1 (1%)
Peyer’s patch, infiltration cellular, plasma cell	1 (1%)	–	–	–
Intestine small, jejunum	(79)	(79)	(82)	(79)
Inflammation, granulomatous	1 (1%)	–	–	–
Epithelium, cyst	1 (1%)	–	–	–
Peyer’s patch, hyperplasia, lymphoid	–	–	1 (1%)	1 (1%)
Liver	(90)	(89)	(90)	(90)
Angiectasis	–	–	2 (2%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Basophilic focus	1 (1%)	2 (2%)	4 (4%)	3 (3%)
Clear cell focus	28 (31%)	34 (38%)	41 (46%)	31 (34%)
Eosinophilic focus	4 (4%)	4 (4%)	8 (9%)	1 (1%)
Extramedullary hematopoiesis	2 (2%)	2 (2%)	2 (2%)	–
Fatty change	37 (41%)	31 (35%)	35 (39%)	35 (39%)
Fibrosis	1 (1%)	–	–	–
Hemorrhage	1 (1%)	–	–	–
Infiltration cellular, lymphocyte	2 (2%)	–	–	2 (2%)
Infiltration cellular, mixed cell	1 (1%)	–	–	–
Inflammation, focal	1 (1%)	1 (1%)	3 (3%)	–
Inflammation, chronic	–	–	–	2 (2%)
Inflammation, chronic active	2 (2%)	–	1 (1%)	1 (1%)
Mixed cell focus	2 (2%)	3 (3%)	7 (8%)	4 (4%)
Necrosis	6 (7%)	6 (7%)	4 (4%)	3 (3%)
Bile duct, cyst	–	2 (2%)	1 (1%)	–
Hepatocyte, fatty change, focal	–	1 (1%)	–	2 (2%)
Mesentery	(12)	(14)	(13)	(17)
Artery, inflammation, chronic active	–	1 (7%)	–	2 (12%)
Fat, hemorrhage	–	1 (7%)	–	–
Fat, inflammation, granulomatous	–	–	–	1 (6%)
Fat, mineral	–	–	1 (8%)	–
Fat, necrosis	8 (67%)	11 (79%)	12 (92%)	13 (76%)
Pancreas	(87)	(88)	(88)	(86)
Hemorrhage	1 (1%)	–	–	–
Infiltration cellular, lymphocyte	3 (3%)	5 (6%)	3 (3%)	1 (1%)
Infiltration cellular, mixed cell	–	–	–	1 (1%)
Inflammation, granulomatous	1 (1%)	–	–	–
Inflammation, acute	–	–	–	1 (1%)
Inflammation, chronic active	–	–	–	1 (1%)
Acinus, atrophy	–	1 (1%)	–	–
Duct, cyst	1 (1%)	2 (2%)	–	–
Duct, fibrosis	1 (1%)	–	–	–
Salivary glands	(90)	(89)	(89)	(89)
Infiltration cellular, lymphocyte	58 (64%)	59 (66%)	65 (73%)	65 (73%)
Stomach, forestomach	(88)	(87)	(89)	(87)
Cyst, squamous	–	–	1 (1%)	3 (3%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Hyperkeratosis	–	1 (1%)	–	2 (2%)
Infiltration cellular, lymphocyte	–	–	1 (1%)	–
Inflammation, chronic	–	–	1 (1%)	–
Epithelium, hyperplasia, focal	3 (3%)	2 (2%)	2 (2%)	–
Epithelium, hyperplasia, diffuse	–	1 (1%)	–	1 (1%)
Stomach, glandular	(87)	(86)	(88)	(85)
Accumulation, hyaline droplet	–	2 (2%)	–	–
Cyst	–	–	–	1 (1%)
Hemorrhage	1 (1%)	–	–	–
Ulcer	–	–	–	1 (1%)
Epithelium, hyperplasia, focal	1 (1%)	–	–	–
Tooth	(27)	(26)	(16)	(20)
Dysplasia	26 (96%)	26 (100%)	14 (88%)	20 (100%)
Inflammation, suppurative	2 (7%)	–	2 (13%)	–
Inflammation, chronic active	–	–	–	1 (5%)
Cardiovascular System				
Aorta	(89)	(89)	(89)	(87)
Blood vessel	(1)	(0)	(0)	(0)
Inflammation, chronic	1 (100%)	–	–	–
Heart	(90)	(89)	(90)	(90)
Bacteria	1 (1%)	2 (2%)	–	–
Cardiomyopathy	10 (11%)	2 (2%)	1 (1%)	2 (2%)
Inflammation, acute	1 (1%)	–	–	–
Inflammation, chronic active	2 (2%)	2 (2%)	–	1 (1%)
Thrombus	1 (1%)	2 (2%)	–	1 (1%)
Artery, inflammation, chronic active	1 (1%)	2 (2%)	–	3 (3%)
Endocardium, mineral	1 (1%)	–	–	–
Endothelium, hyperplasia	–	1 (1%)	–	1 (1%)
Epicardium, inflammation, chronic	1 (1%)	–	–	–
Epicardium, mineral	1 (1%)	–	–	–
Myocardium, hemorrhage	–	1 (1%)	–	–
Myocardium, mineral	2 (2%)	2 (2%)	1 (1%)	1 (1%)
Myocardium, necrosis	1 (1%)	2 (2%)	–	–
Endocrine System				
Adrenal cortex	(90)	(89)	(89)	(88)
Accessory adrenal cortical nodule	1 (1%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Angiectasis	1 (1%)	–	–	–
Hyperplasia, focal	3 (3%)	1 (1%)	6 (7%)	6 (7%)
Hypertrophy, focal	2 (2%)	8 (9%)	9 (10%)	1 (1%)
Infiltration cellular, mononuclear cell	–	–	–	1 (1%)
Bilateral, hyperplasia, focal	–	–	1 (1%)	–
Bilateral, hypertrophy, focal	1 (1%)	5 (6%)	4 (4%)	1 (1%)
Subcapsular, hyperplasia	69 (77%)	72 (81%)	80 (90%)	72 (82%)
Adrenal medulla	(90)	(88)	(88)	(86)
Islets, pancreatic	(88)	(88)	(90)	(89)
Atrophy	–	–	–	1 (1%)
Hyperplasia	18 (20%)	20 (23%)	16 (18%)	10 (11%)
Infiltration cellular, lymphocyte	2 (2%)	1 (1%)	2 (2%)	–
Parathyroid gland	(68)	(68)	(67)	(66)
Cyst	–	2 (3%)	4 (6%)	1 (2%)
Pituitary gland	(86)	(85)	(87)	(85)
Pars distalis, angiectasis	1 (1%)	–	–	–
Pars distalis, cyst	3 (3%)	4 (5%)	3 (3%)	4 (5%)
Pars distalis, hyperplasia, focal	1 (1%)	2 (2%)	1 (1%)	–
Thyroid gland	(89)	(88)	(88)	(88)
Infiltration cellular, lymphocyte	–	–	1 (1%)	1 (1%)
General Body System				
Peritoneum	(1)	(0)	(0)	(0)
Tissues NOS	(0)	(0)	(0)	(1)
Genital System				
Coagulating gland	(2)	(2)	(0)	(4)
Cyst	2 (100%)	1 (50%)	–	3 (75%)
Bilateral, inflammation, chronic active	–	1 (50%)	–	–
Epididymis	(90)	(89)	(90)	(90)
Granuloma sperm	1 (1%)	1 (1%)	1 (1%)	1 (1%)
Infiltration cellular, lymphocyte	29 (32%)	17 (19%)	22 (24%)	28 (31%)
Spermatocele	–	–	–	1 (1%)
Bilateral, duct, atrophy	–	–	–	1 (1%)
Preputial gland	(89)	(88)	(90)	(89)
Infiltration cellular, lymphocyte	43 (48%)	32 (36%)	38 (42%)	33 (37%)
Inflammation, suppurative	1 (1%)	–	–	–
Inflammation, chronic active	1 (1%)	–	1 (1%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Bilateral, hyperplasia	–	–	1 (1%)	–
Bilateral, duct, dilation	6 (7%)	2 (2%)	9 (10%)	2 (2%)
Duct, dilation	10 (11%)	6 (7%)	11 (12%)	4 (4%)
Duct, inflammation, chronic active	–	–	1 (1%)	–
Duct, necrosis	1 (1%)	–	–	–
Prostate	(90)	(87)	(90)	(87)
Hyperplasia, focal	–	–	–	1 (1%)
Infiltration cellular, lymphocyte	4 (4%)	3 (3%)	6 (7%)	9 (10%)
Inflammation, acute	–	1 (1%)	–	5 (6%)
Inflammation, chronic active	1 (1%)	–	1 (1%)	–
Seminal vesicle	(90)	(88)	(90)	(90)
Dilation	4 (4%)	4 (5%)	5 (6%)	4 (4%)
Hyperplasia	–	–	–	1 (1%)
Inflammation, chronic active	1 (1%)	1 (1%)	–	–
Bilateral, atrophy	–	–	–	1 (1%)
Bilateral, dilation	27 (30%)	26 (30%)	23 (26%)	29 (32%)
Bilateral, fibrosis	–	–	–	1 (1%)
Bilateral, inflammation, acute	–	–	–	1 (1%)
Bilateral, inflammation, chronic	–	1 (1%)	1 (1%)	–
Bilateral, inflammation, chronic active	–	–	–	1 (1%)
Testis	(90)	(88)	(90)	(90)
Bilateral, germ cell, degeneration	–	–	–	1 (1%)
Germ cell, degeneration	2 (2%)	1 (1%)	1 (1%)	–
Hematopoietic System				
Bone marrow	(90)	(88)	(90)	(90)
Hypercellularity	3 (3%)	–	2 (2%)	3 (3%)
Lymph node	(6)	(8)	(7)	(9)
Bronchial, infiltration cellular, mixed cell	–	–	–	1 (11%)
Iliac, erythrophagocytosis	–	1 (13%)	–	–
Iliac, hemorrhage	–	1 (13%)	–	–
Iliac, hyperplasia, lymphoid	–	1 (13%)	–	2 (22%)
Iliac, infiltration cellular, histiocyte	–	2 (25%)	2 (29%)	–
Iliac, infiltration cellular, plasma cell	–	–	–	1 (11%)
Iliac, pigment	–	–	2 (29%)	–
Lumbar, hemorrhage	–	–	–	1 (11%)
Mediastinal, hyperplasia, lymphoid	–	–	–	1 (11%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Mediastinal, infiltration cellular, plasma cell	–	1 (13%)	–	–
Pancreatic, hyperplasia, lymphoid	–	–	2 (29%)	–
Renal, hemorrhage	1 (17%)	–	1 (14%)	–
Renal, hyperplasia, lymphoid	–	–	1 (14%)	–
Renal, infiltration cellular, mixed cell	–	–	–	1 (11%)
Lymph node, mandibular	(72)	(61)	(63)	(60)
Hemorrhage	–	1 (2%)	–	–
Hyperplasia, lymphoid	2 (3%)	–	–	–
Infiltration cellular, histiocyte	1 (1%)	–	–	1 (2%)
Lymph node, mesenteric	(85)	(82)	(88)	(83)
Erythrophagocytosis	1 (1%)	5 (6%)	4 (5%)	1 (1%)
Hemorrhage	10 (12%)	11 (13%)	7 (8%)	13 (16%)
Hyperplasia, lymphoid	4 (5%)	2 (2%)	2 (2%)	5 (6%)
Infiltration cellular, histiocyte	8 (9%)	7 (9%)	5 (6%)	4 (5%)
Infiltration cellular, mixed cell	–	2 (2%)	–	–
Infiltration cellular, plasma cell	1 (1%)	1 (1%)	1 (1%)	1 (1%)
Spleen	(87)	(88)	(89)	(88)
Extramedullary hematopoiesis	15 (17%)	15 (17%)	13 (15%)	12 (14%)
Hyperplasia, lymphoid	5 (6%)	2 (2%)	5 (6%)	3 (3%)
White pulp, atrophy	–	–	1 (1%)	–
Thymus	(75)	(83)	(81)	(72)
Atrophy	11 (15%)	16 (19%)	4 (5%)	14 (19%)
Cyst	11 (15%)	16 (19%)	26 (32%)	15 (21%)
Hemorrhage	1 (1%)	1 (1%)	1 (1%)	–
Infiltration cellular, histiocyte	–	–	–	1 (1%)
Integumentary System				
Mammary gland	(2)	(5)	(2)	(8)
Skin	(90)	(89)	(90)	(90)
Cyst, squamous	–	–	–	1 (1%)
Hyperkeratosis	–	1 (1%)	–	–
Infiltration cellular, mixed cell	1 (1%)	–	–	–
Inflammation, chronic	–	1 (1%)	–	–
Ulcer	2 (2%)	2 (2%)	2 (2%)	1 (1%)
Epidermis, hyperplasia, focal	–	1 (1%)	–	–
Hair follicle, atrophy	–	–	–	2 (2%)
Subcutaneous tissue, inflammation, granulomatous	–	–	1 (1%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Musculoskeletal System				
Bone	(90)	(88)	(90)	(90)
Callus	–	–	–	1 (1%)
Increased bone	–	–	1 (1%)	–
Skeletal muscle	(90)	(89)	(90)	(90)
Degeneration	1 (1%)	–	–	1 (1%)
Infiltration cellular, lymphocyte	3 (3%)	–	5 (6%)	5 (6%)
Inflammation, acute	–	1 (1%)	–	1 (1%)
Inflammation, chronic active	–	–	–	1 (1%)
Necrosis	–	1 (1%)	–	–
Nervous System				
Brain	(90)	(89)	(90)	(90)
Hemorrhage	2 (2%)	2 (2%)	–	–
Infiltration cellular, lymphocyte	1 (1%)	–	–	–
Inflammation, acute	–	1 (1%)	–	–
Mineral	79 (88%)	81 (91%)	80 (89%)	76 (84%)
Squamous cyst	–	–	1 (1%)	–
Artery, meninges, inflammation, chronic active	1 (1%)	–	–	1 (1%)
Brain trigeminal ganglion	(69)	(79)	(72)	(79)
Nerve trigeminal	(67)	(53)	(66)	(63)
Peripheral nerve, sciatic	(89)	(89)	(90)	(89)
Axon, degeneration	9 (10%)	9 (10%)	9 (10)	4 (4%)
Spinal cord	(90)	(89)	(90)	(90)
Cyst, squamous	–	–	1 (1%)	–
Degeneration	–	1 (1%)	–	–
Hemorrhage	–	1 (1%)	–	–
Necrosis	1 (1%)	1 (1%)	–	1 (1%)
Artery, meninges, inflammation, chronic active	1 (1%)	–	2 (2%)	1 (1%)
Respiratory System				
Lung	(90)	(89)	(90)	(90)
Congestion	2 (2%)	2 (2%)	3 (3%)	3 (3%)
Hemorrhage	3 (3%)	5 (6%)	4 (4%)	3 (3%)
Infiltration cellular, histiocyte	6 (7%)	1 (1%)	1 (1%)	2 (2%)
Infiltration cellular, lymphocyte	1 (1%)	–	1 (1%)	–
Infiltration, chronic active	–	1 (1%)	–	–
Alveolar epithelium, hyperplasia, focal	6 (7%)	8 (9%)	8 (9%)	7 (8%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Bronchiole, foreign body	1 (1%)	–	–	–
Bronchiole, inflammation, suppurative	1 (1%)	–	–	–
Mediastinum	(0)	(0)	(2)	(1)
Nose	(90)	(89)	(90)	(89)
Inflammation, acute	1 (1%)	–	–	–
Respiratory epithelium, accumulation, hyaline droplet	1 (1%)	–	–	–
Respiratory epithelium, hyperplasia	5 (6%)	–	–	–
Vomeronasal organ, fibrosis	1 (1%)	–	–	–
Trachea	(90)	(89)	(89)	(90)
Special Senses System				
Eye	(90)	(89)	(90)	(90)
Phthisis bulbi	–	1 (1%)	3 (3%)	1 (1%)
Cornea, fibrosis	1 (1%)	–	–	–
Cornea, inflammation, chronic active	–	–	–	1 (1%)
Optic nerve, degeneration	–	–	1 (1%)	–
Retina, atrophy	–	–	–	1 (1%)
Retina, degeneration	–	–	1 (1%)	–
Harderian gland	(88)	(89)	(90)	(90)
Hemorrhage	1 (1%)	–	–	–
Hyperplasia, focal	2 (2%)	1 (1%)	2 (2%)	1 (1%)
Infiltration cellular, lymphocyte	36 (41%)	36 (40%)	32 (36%)	40 (44%)
Urinary System				
Kidney	(90)	(89)	(90)	(89)
Bacteria	–	1 (1%)	–	–
Infarct	7 (8%)	4 (4%)	4 (4%)	8 (9%)
Infiltration cellular, histiocyte	–	1 (1%)	–	–
Infiltration cellular, mixed cell	–	1 (1%)	–	–
Inflammation, suppurative	1 (1%)	–	–	–
Inflammation, granulomatous	1 (1%)	–	–	–
Inflammation, acute	–	1 (1%)	–	–
Metaplasia, osseous	3 (3%)	6 (7%)	5 (6%)	1 (1%)
Mineral	–	2 (2%)	–	–
Nephropathy, chronic progressive	74 (82%)	66 (74%)	76 (84%)	74 (83%)
Bilateral, bacteria	–	1 (1%)	–	–
Bilateral, inflammation, acute	–	1 (1%)	–	1 (1%)
Bilateral, renal tubule, bacteria	–	–	–	1 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Bilateral, renal tubule, pigment	–	1 (1%)	–	1 (1%)
Glomerulus, cyst	1 (1%)	–	–	1 (1%)
Interstitium, infiltration cellular, lymphocyte	41 (46%)	50 (56%)	56 (62%)	44 (49%)
Pelvis, dilation	1 (1%)	–	–	1 (1%)
Renal tubule, accumulation, hyaline droplet	–	–	–	1 (1%)
Renal tubule, bacteria	–	1 (1%)	–	–
Renal tubule, cyst	8 (9%)	3 (3%)	4 (4%)	5 (6%)
Renal tubule, dilation	–	–	–	1 (1%)
Renal tubule, mineral	1 (1%)	–	–	4 (4%)
Urothelium, inflammation, chronic active	1 (1%)	–	–	–
Urinary bladder	(87)	(88)	(90)	(89)
Hemorrhage	3 (3%)	–	–	–
Infiltration cellular, lymphocyte	26 (30%)	20 (23%)	24 (27%)	21 (24%)
Inflammation, acute	–	1 (1%)	–	–
Inflammation, chronic active	–	1 (1%)	–	–
Transitional epithelium, hyperplasia, diffuse	–	1 (1%)	–	–
Transitional epithelium, hyperplasia, multifocal	–	2 (2%)	–	–

[a]Number of animals examined microscopically at the site and the number of animals with lesion.

Appendix B. Summary of Lesions in Female Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

Tables

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Table B-1. Summary of the Incidence of Neoplasms in Female Mice Exposed to GSM-modulated Cell Phone RFR for Two Years[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Disposition Summary				
Animals initially in study	105	105	105	105
14-week interim evaluation	15	15	15	15
Early deaths				
Moribund	9	9	9	6
Natural deaths	14	7	11	11
Survivors				
Died last week of study	1	4	2	1
Terminal euthanasia	66	70	68	72
Animals examined microscopically	100	100	100	100
Systems Examined at 14 Weeks with No Neoplasms Observed				
Alimentary System				
Cardiovascular System				
Endocrine System				
General Body System				
Genital System				
Hematopoietic System				
Integumentary System				
Musculoskeletal System				
Nervous System				
Respiratory System				
Special Senses System				
Urinary System				
Two-year Study				
Alimentary System				
Esophagus	(87)	(90)	(87)	(90)
Gallbladder	(79)	(75)	(74)	(72)
Intestine large, cecum	(84)	(82)	(83)	(82)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Leiomyosarcoma	–	–	–	1 (1%)
Intestine large, colon	(84)	(84)	(86)	(85)
Intestine large, rectum	(88)	(86)	(88)	(86)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Osteosarcoma, metastatic, skin	1 (1%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Intestine small, duodenum	(82)	(83)	(84)	(81)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Intestine small, ileum	(83)	(82)	(82)	(80)
Intestine small, jejunum	(84)	(81)	(81)	(80)
Adenoma	–	1 (1%)	–	–
Liver	(89)	(90)	(90)	(89)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Hemangiosarcoma	–	1 (1%)	–	1 (1%)
Hepatoblastoma	1 (1%)	–	–	–
Hepatocellular adenoma	14 (16%)	16 (18%)	11 (12%)	8 (9%)
Hepatocellular adenoma, multiple	5 (6%)	2 (2%)	2 (2%)	2 (2%)
Hepatocellular carcinoma	6 (7%)	6 (7%)	5 (6%)	5 (6%)
Hepatocellular carcinoma, multiple	2 (2%)	–	1 (1%)	1 (1%)
Hepatocholangiocarcinoma	–	–	1 (1%)	–
Osteosarcoma, metastatic, bone	1 (1%)	–	–	–
Osteosarcoma, metastatic, skin	1 (1%)	–	–	–
Mesentery	(29)	(24)	(32)	(30)
Fibrosarcoma, metastatic, skin	1 (3%)	–	–	–
Renal mesenchymal tumor, metastatic, kidney	1 (3%)	–	–	–
Fat, hemangioma	1 (3%)	–	–	–
Fat, lipoma	–	1 (4%)	–	1 (3%)
Oral mucosa	(0)	(0)	(2)	(0)
Pancreas	(87)	(88)	(89)	(86)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Hemangioma	–	–	–	1 (1%)
Hepatocellular carcinoma, metastatic, liver	–	–	1 (1%)	–
Renal mesenchymal tumor, metastatic, kidney	1 (1%)	–	–	–
Acinus, carcinoma	–	–	1 (1%)	–
Salivary glands	(89)	(89)	(90)	(90)
Adenocarcinoma, metastatic, Harderian gland	–	1 (1%)	–	–
Stomach, forestomach	(86)	(89)	(90)	(85)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Squamous cell papilloma	1 (1%)	–	–	–
Stomach, glandular	(85)	(87)	(85)	(85)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Tongue	(0)	(0)	(1)	(0)
Tooth	(0)	(0)	(1)	(0)
Cardiovascular System				
Aorta	(84)	(88)	(90)	(89)
Blood vessel	(0)	(0)	(2)	(0)
Heart	(90)	(90)	(90)	(90)
Adenocarcinoma, metastatic, Harderian gland	–	1 (1%)	–	–
Hemangioma	–	–	1 (1%)	–
Osteosarcoma, metastatic, skin	1 (1%)	–	–	–
Endocrine System				
Adrenal cortex	(84)	(88)	(90)	(90)
Adenoma	1 (1%)	–	–	–
Adrenal medulla	(83)	(84)	(86)	(87)
Pheochromocytoma benign	–	–	1 (1%)	–
Pheochromocytoma malignant	2 (2%)	–	–	–
Islets, pancreatic	(87)	(88)	(90)	(86)
Adenoma	–	–	1 (1%)	1 (1%)
Carcinoma	1 (1%)	1 (1%)	–	–
Parathyroid gland	(60)	(57)	(64)	(62)
Pituitary gland	(80)	(80)	(84)	(84)
Pars distalis, adenoma	6 (8%)	5 (6%)	7 (8%)	5 (6%)
Pars distalis, carcinoma	–	–	2 (2%)	1 (1%)
Thyroid gland	(86)	(89)	(86)	(86)
C-cell, carcinoma	1 (1%)	–	–	–
Follicular cell, carcinoma	–	–	1 (1%)	–
General Body System				
Peritoneum	(0)	(0)	(1)	(0)
Tissue NOS	(1)	(1)	(1)	(2)
Hemangiosarcoma	–	–	–	1 (50%)
Abdominal, osteosarcoma, metastatic, skin	1 (100%)	–	–	–
Genital System				
Clitoral gland	(82)	(84)	(80)	(86)
Ovary	(75)	(86)	(82)	(80)
Cystadenoma	2 (3%)	2 (2%)	3 (4%)	6 (8%)
Granulosa cell tumor benign	1 (1%)	–	1 (1%)	1 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Hemangioma	2 (3%)	2 (2%)	–	–
Hemangiosarcoma	–	1 (1%)	–	–
Luteoma	–	1 (1%)	–	–
Teratoma benign	–	–	2 (2%)	1 (1%)
Thecoma malignant	1 (1%)	–	–	–
Oviduct	(0)	(0)	(1)	(0)
Uterus	(89)	(90)	(90)	(89)
Adenocarcinoma	–	–	–	1 (1%)
Fibroma	1 (1%)	–	–	–
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Hemangiosarcoma	–	–	1 (1%)	–
Leiomyoma	1 (1%)	–	–	–
Polyp stromal	–	3 (3%)	2 (2%)	2 (2%)
Vagina	(0)	(0)	(1)	(0)
Hematopoietic System				
Bone marrow	(90)	(89)	(89)	(90)
Hemangiosarcoma	–	–	2 (2%)	1 (1%)
Lymph node	(18)	(20)	(16)	(14)
Bronchial, alveolar/bronchiolar carcinoma, metastatic, lung	1 (6%)	–	–	–
Bronchial, fibrosarcoma, metastatic, skin	1 (6%)	–	–	–
Lymph node, mandibular	(76)	(77)	(81)	(83)
Lymph node, mesenteric	(71)	(84)	(80)	(83)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Hemangiosarcoma	–	–	–	1 (1%)
Renal mesenchymal tumor, metastatic, kidney	1 (1%)	–	–	–
Spleen	(86)	(87)	(89)	(87)
Hemangiosarcoma	–	2 (2%)	2 (2%)	–
Thymus	(85)	(80)	(84)	(86)
Integumentary System				
Mammary gland	(85)	(88)	(88)	(84)
Adenocarcinoma	–	–	1 (1%)	1 (1%)
Skin	(90)	(90)	(90)	(90)
Sebaceous gland, adenoma	–	1 (1%)	–	–
Subcutaneous tissue, fibroma	1 (1%)	–	–	–
Subcutaneous tissue, fibrosarcoma	3 (3%)	–	3 (3%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Subcutaneous tissue, hemangiosarcoma	2 (2%)	–	–	–
Subcutaneous tissue, lipoma	1 (1%)	–	–	–
Subcutaneous tissue, malignant fibrous histiocytoma	–	1 (1%)	3 (3%)	–
Subcutaneous tissue, osteosarcoma	1 (1%)	–	–	–
Subcutaneous tissue, sarcoma	2 (2%)	–	1 (1%)	1 (1%)
Musculoskeletal System				
Bone	(90)	(90)	(89)	(90)
Hemangioma	1 (1%)	–	–	–
Hemangiosarcoma	–	1 (1%)	–	–
Osteosarcoma	1 (1%)	–	–	–
Skeletal muscle	(89)	(90)	(90)	(90)
Adenocarcinoma, metastatic, Harderian gland	–	1 (1%)	–	–
Osteosarcoma	1 (1%)	–	–	1 (1%)
Rhabdomyosarcoma	–	–	–	1 (1%)
Sarcoma, metastatic, skin	–	–	1 (1%)	–
Nervous System				
Brain	(87)	(90)	(90)	(90)
Carcinoma, metastatic, pituitary gland	–	–	2 (2%)	1 (1%)
Meningioma benign	–	1 (1%)	–	–
Osteosarcoma, metastatic, skeletal muscle	1 (1%)	–	–	–
Brain trigeminal ganglion	(75)	(74)	(80)	(79)
Nerve trigeminal	(56)	(58)	(53)	(35)
Carcinoma, metastatic, pituitary gland	–	–	–	1 (3%)
Peripheral nerve	(0)	(0)	(1)	(0)
Peripheral nerve, sciatic	(88)	(87)	(88)	(88)
Spinal cord	(90)	(90)	(90)	(90)
Respiratory System				
Larynx	(0)	(0)	(2)	(0)
Lung	(90)	(90)	(90)	(90)
Adenocarcinoma, metastatic, Harderian gland	–	1 (1%)	–	–
Alveolar/bronchiolar adenoma	3 (3%)	5 (6%)	7 (8%)	1 (1%)
Alveolar/bronchiolar adenoma, multiple	–	1 (1%)	–	–
Alveolar/bronchiolar carcinoma	3 (3%)	1 (1%)	–	1 (1%)
Carcinoma, metastatic, pancreas	–	–	1 (1%)	–
Carcinoma, metastatic, thyroid gland	1 (1%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Fibrosarcoma, metastatic, skin	1 (1%)	–	2 (2%)	–
Hepatocellular carcinoma, metastatic, liver	2 (2%)	–	2 (2%)	1 (1%)
Hepatocholangiocarcinoma, metastatic, liver	–	–	1 (1%)	–
Osteosarcoma, metastatic, bone	1 (1%)	–	–	–
Osteosarcoma, metastatic, skeletal muscle	1 (1%)	–	–	–
Osteosarcoma, metastatic, skin	1 (1%)	–	–	–
Sarcoma, metastatic, skin	–	–	1 (1%)	–
Mediastinum	(2)	(0)	(0)	(0)
Hepatocellular carcinoma, metastatic, liver	1 (50%)	–	–	–
Nose	(89)	(90)	(90)	(90)
Adenocarcinoma, metastatic, Harderian gland	–	1 (1%)	–	–
Pleura	(0)	(0)	(1)	(0)
Trachea	(90)	(89)	(90)	(90)
Special Senses System				
Ear	(0)	(0)	(1)	(0)
Eye	(89)	(88)	(90)	(90)
Harderian gland	(89)	(90)	(90)	(87)
Adenocarcinoma	–	1 (1%)	1 (1%)	–
Adenoma	4 (4%)	7 (8%)	5 (6%)	6 (7%)
Lacrimal gland	(0)	(1)	(2)	(0)
Zymbal's gland	(0)	(0)	(1)	(0)
Urinary System				
Kidney	(89)	(87)	(89)	(88)
Renal mesenchymal tumor	1 (1%)	–	–	–
Renal tubule, adenoma	2 (2%)	–	–	–
Ureter	(0)	(0)	(1)	(0)
Urethra	(0)	(0)	(1)	(0)
Urinary bladder	(86)	(87)	(86)	(86)
Systemic Lesions				
Multiple organs[b]	(90)	(90)	(90)	(90)
Histiocytic sarcoma	8 (9%)	2 (2%)	8 (9%)	5 (6%)
Leukemia erythrocytic	–	1 (1%)	–	–
Lymphoma malignant	2 (2%)	13 (14%)	9 (10%)	6 (7%)
Neoplasm Summary				
Total animals with primary neoplasms[c]				

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Two-year study	59	55	57	44
Total primary neoplasms				
Two-year study	85	79	85	64
Total animals with benign neoplasms				
Two-year study	36	37	35	29
Total benign neoplasms				
Two-year study	47	48	43	35
Total animals with malignant neoplasms				
Two-year study	33	27	35	24
Total malignant neoplasms				
Two-year study	38	31	42	29
Total animals with metastatic neoplasms				
Two-year study	9	1	9	2
Total metastatic neoplasms				
Two-year study	29	5	11	3

[a]Number of animals examined microscopically at the site and the number of animals with neoplasm.
[b]Number of animals with any tissue examined microscopically.
[c]Primary neoplasms: all neoplasms except metastatic neoplasms.

Table B-2. Statistical Analysis of Primary Neoplasms in Female Mice Exposed to GSM-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Harderian Gland: Adenoma				
Overall rate[a]	4/90 (4%)	7/90 (8%)	5/90 (6%)	6/90 (7%)
Adjusted rate[b]	5.0%	8.3%	6.0%	7.2%
Terminal rate[c]	4/67 (6%)	4/72 (6%)	5/69 (7%)	6/72 (8%)
First incidence (days)	739 (T)	562	739 (T)	739 (T)
Poly-3 test[d]	P = 0.436	P = 0.299	P = 0.524	P = 0.398
Harderian Gland: Adenoma or Carcinoma				
Overall rate	4/90 (4%)	8/90 (9%)	6/90 (7%)	6/90 (7%)
Adjusted rate	5.0%	9.4%	7.2%	7.2%
Terminal rate	4/67 (6%)	4/72 (6%)	6/69 (9%)	6/72 (8%)
First incidence (days)	739 (T)	562	739 (T)	739 (T)
Poly-3 test	P = 0.471	P = 0.214	P = 0.397	P = 0.398
Liver: Hepatocellular Adenoma				
Overall rate	19/89 (21%)[e]	18/90 (20%)	13/90 (14%)	10/89 (11%)
Adjusted rate	23.6%	21.5%	15.6%	12.0%
Terminal rate	17/67 (25%)	17/72 (24%)	11/69 (16%)	9/72 (13%)
First incidence (days)	511	638	674	700
Poly-3 test	P = 0.022N	P = 0.448N	P = 0.134N	P = 0.041N
Liver: Hepatocellular Carcinoma				
Overall rate	8/89 (9%)	6/90 (7%)	6/90 (7%)	6/89 (7%)
Adjusted rate	10.0%	7.2%	7.2%	7.2%
Terminal rate	7/67 (10%)	4/72 (6%)	5/69 (7%)	4/72 (6%)
First incidence (days)	656	650	701	720
Poly-3 test	P = 0.348N	P = 0.354N	P = 0.358N	P = 0.361N
Liver: Hepatocellular Adenoma or Carcinoma				
Overall rate	25/89 (28%)	24/90 (27%)	17/90 (19%)	15/89 (17%)
Adjusted rate	30.9%	28.5%	20.3%	18.0%
Terminal rate	22/67 (33%)	21.72 (29%)	14/69 (20%)	12/72 (17%)
First incidence (days)	511	638	674	700
Poly-3 test	P = 0.020N	P = 0.436N	P = 0.082N	P = 0.040N
Liver: Hepatocellular Carcinoma or Hepatoblastoma				
Overall rate	9/89 (10%)	6/90 (7%)	6/90 (7%)	6/89 (7%)
Adjusted rate	11.3%	7.2%	7.2%	7.2%
Terminal rate	8/67 (12%)	4/72 (6%)	5/69 (7%)	4/72 (6%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
First incidence (days)	656	650	701	720
Poly-3 test	P = 0.268N	P = 0.261N	P = 0.265N	P = 0.267N
Lung: Alveolar/bronchiolar Adenoma				
Overall rate	3/90 (3%)	6/90 (7%)	7/90 (8%)	1/90 (1%)
Adjusted rate	3.8%	7.2%	8.4%	1.2%
Terminal rate	3/67 (5%)	6/72 (8%)	7/69 (10%)	1/72 (1%)
First incidence (days)	739 (T)	739 (T)	739 (T)	739 (T)
Poly-3 test	P = 0.190N	P = 0.268	P = 0.180	P = 0.292N
Lung: Alveolar/bronchiolar Adenoma or Carcinoma				
Overall rate	6/90 (7%)	6/90 (7%)	7/90 (8%)	2/90 (2%)
Adjusted rate	7.5%	7.2%	8.4%	2.4%
Terminal rate	5/67 (8%)	6/72 (8%)	7/69 (10%)	2/72 (3%)
First incidence (days)	607	739 (T)	739 (T)	739 (T)
Poly-3 test	P = 0.108N	P = 0.592N	P = 0.526	P = 0.127N
Ovary: Cystadenoma				
Overall rate	2/75 (3%)	2/86 (2%)	3/82 (4%)	6/80 (8%)
Adjusted rate	3.0%	2.5%	3.9%	7.9%
Terminal rate	2/56 (4%)	2/69 (3%)	3/65 (5%)	6/67 (9%)
First incidence (days)	739 (T)	739 (T)	739 (T)	739 (T)
Poly-3 test	P = 0.067	P = 0.623N	P = 0.564	P = 0.186
Pituitary Gland (Pars Distalis): Adenoma				
Overall rate	6/80 (8%)	5/80 (6%)	7/84 (8%)	5/84 (6%)
Adjusted rate	8.4%	6.8%	9.0%	6.4%
Terminal rate	5/60 (8%)	5/65 (8%)	4/64 (6%)	5/68 (7%)
First incidence (days)	703	739 (T)	712	739 (T)
Poly-3 test	P = 0.417N	P = 0.475N	P = 0.563	P = 0.435N
Pituitary Gland (Pars Distalis): Adenoma or Carcinoma				
Overall rate	6/80 (8%)	5/80 (6%)	9/84 (11%)	6/84 (7%)
Adjusted rate	8.4%	6.8%	11.5%	7.6%
Terminal rate	5/60 (8%)	5/65 (8%)	4/64 (6%)	5/68 (7%)
First incidence (days)	703	739 (T)	606	676
Poly-3 test	P = 0.553	P = 0.475N	P = 0.362	P = 0.549N
Skin (Subcutaneous Tissue): Fibrosarcoma or Sarcoma				
Overall rate	5/90 (6%)	0/90 (0%)	4/90 (4%)	1/90 (1%)
Adjusted rate	6.2%	0.0%	4.8%	1.2%

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Terminal rate	1/67 (2%)	0/72 (0%)	1/69 (1%)	0/72 (0%)
First incidence (days)	607	–[f]	646	607
Poly-3 test	P = 0.159N	P = 0.031N	P = 0.478N	P = 0.098N
Skin (Subcutaneous Tissue): Fibroma, Fibrosarcoma, or Sarcoma				
Overall rate	6/90 (7%)	0/90 (0%)	4/90 (4%)	1/90 (1%)
Adjusted rate	7.4%	0.0%	4.8%	1.2%
Terminal rate	2/67 (3%)	0/72 (0%)	1/69 (1%)	0/72 (0%)
First incidence (days)	607	–	646	607
Poly-3 test	P = 0.094N	P = 0.016N	P = 0.351N	P = 0.055N
Skin (Subcutaneous Tissue): Fibrosarcoma, Sarcoma, or Malignant Fibrous Histiocytoma				
Overall rate	5/90 (6%)	1/90 (1%)	7/90 (8%)	1/90 (1%)
Adjusted rate	6.2%	1.2%	8.4%	1.2%
Terminal rate	1/67 (2%)	0/72 (0%)	3/69 (4%)	0/72 (0%)
First incidence (days)	607	562	646	607
Poly-3 test	P = 0.193N	P = 0.097N	P = 0.407	P = 0.098N
Skin (Subcutaneous Tissue): Fibroma, Fibrosarcoma, Sarcoma, or Malignant Fibrous Histiocytoma				
Overall rate	6/90 (7%)	1/90 (1%)	7/90 (8%)	1/90 (1%)
Adjusted rate	7.4%	1.2%	8.4%	1.2%
Terminal rate	2/67 (3%)	0/72 (0%)	3/69 (4%)	0/72 (0%)
First incidence (days)	607	562	646	607
Poly-3 test	P = 0.125N	P = 0.054N	P = 0.527	P = 0.055N
All Organs: Hemangiosarcoma				
Overall rate	2/90 (2%)	5/90 (6%)	3/90 (3%)	3/90 (3%)
Adjusted rate	2.5%	6.0%	3.6%	3.6%
Terminal rate	1/67 (2%)	4/72 (6%)	1/69 (1%)	2/72 (3%)
First incidence (days)	703	638	629	720
Poly-3 test	P = 0.572N	P = 0.238	P = 0.521	P = 0.518
All Organs: Hemangioma or Hemangiosarcoma				
Overall rate	6/90 (7%)	7/90 (8%)	4/90 (4%)	4/90 (4%)
Adjusted rate	7.5%	8.4%	4.8%	4.8%
Terminal rate	5/97 (8%)	6/72 (8%)	1/69 (1%)	3/72 (4%)
First incidence (days)	703	638	629	720
Poly-3 test	P = 0.218N	P = 0.533	P = 0.343N	P = 0.348N

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
All Organs: Histiocytic Sarcoma				
Overall rate	8/90 (9%)	2/90 (2%)	8/90 (9%)	5/90 (6%)
Adjusted rate	9.7%	2.4%	9.5%	5.9%
Terminal rate	2/67 (3%)	1/72 (1%)	3/69 (4%)	1/72 (1%)
First incidence (days)	562	458	629	660
Poly-3 test	P = 0.419N	P = 0.048N	P = 0.587N	P = 0.270N
All Organs: Malignant Lymphoma				
Overall rate	2/90 (2%)	13/90 (14%)	9/90 (10%)	6/90 (7%)
Adjusted rate	2.5%	15.6%	10.7%	7.1%
Terminal rate	1/67 (1%)	12/72 (17%)	5/69 (7%)	3/72 (4%)
First incidence (days)	604	731	516	590
Poly-3 test	P = 0.474	P = 0.004	P = 0.035	P = 0.153
All Organs: Benign Neoplasms				
Overall rate	36/90 (40%)	37/90 (41%)	35/90 (39%)	29/90 (32%)
Adjusted rate	44.1%	43.2%	41.7%	34.3%
Terminal rate	32/67 (48%)	31/72 (43%)	29/69 (42%)	26/72 (36%)
First incidence (days)	511	403	674	390
Poly-3 test	P = 0.094N	P = 0.515N	P = 0.439N	P = 0.127N
All Organs: Malignant Neoplasms				
Overall rate	33/90 (37%)	27/90 (30%)	35/90 (39%)	24/90 (27%)
Adjusted rate	38.1%	31.4%	39.8%	27.9%
Terminal rate	17/67 (25%)	19/72 (26%)	17/69 (25%)	12/72 (17%)
First incidence (days)	448	458	516	590
Poly-3 test	P = 0.139N	P = 0.220N	P = 0.469	P = 0.101N
All Organs: Benign or Malignant Neoplasms				
Overall rate	59/90 (66%)	55/90 (61%)	57/90 (63%)	44/90 (49%)
Adjusted rate	67.6%	62.8%	64.7%	50.6%
Terminal rate	42/67 (63%)	43/72 (60%)	38/69 (55%)	31/72 (43%)
First incidence (days)	448	403	516	390
Poly-3 test	P = 0.012N	P = 0.303N	P = 0.401N	P = 0.015N

(T) = terminal euthanasia.
[a]Number of neoplasm-bearing animals/number of animals examined. Denominator is number of animals examined microscopically for liver, lung, ovary, and pituitary gland; for other tissues, denominator is number of animals necropsied.
[b]Poly-3 estimated neoplasm incidence after adjustment for intercurrent mortality.
[c]Observed incidence at terminal euthanasia.
[d]Beneath the sham control incidence is the P value associated with the trend test. Beneath the exposed group incidence are the P values corresponding to pairwise comparisons between the sham controls and that exposed group. The Poly-3 test accounts for differential mortality in animals that do not reach terminal euthanasia. A negative trend or a lower incidence in an exposure group is indicated by **N**.

[e]A single incidence of hepatoblastoma occurred in an animal that also had an adenoma.
[f]Not applicable; no neoplasms in animal group.

Table B-3. Historical Incidence of Malignant Lymphoma in Control Female B6C3F1/N Mice[a]

Study (Study Start)	Incidence in Controls
Historical Incidence: All Studies	
Antimony trioxide (October 2008)	7/50
2,3-Butanedione (August 2009)	9/50
Green tea extract (July 2007)	7/50
2-Hydroxy-4-methoxybenzophenone (July 2010)	5/50
Indole-3-carbinol (April 2007)	6/50
CIMSTAR 3800 (May 2008)	18/50
Trim VX (August 2009)	10/50
p-Chloro-α,α,α-trifluorotoluene (January 2011)	9/50
Pentabromodiphenyl ether mixture [DE-71 (technical grade)] (February 2008)	7/50
Radiofrequency radiation (June 2012)	2/90
Tetrabromobisphenol A (August 2007)	9/50
Overall Historical Incidence	
Total (%)	89/590 (15.1%)
Mean ± standard deviation	16.0% ± 8.3%
Range	2%–36%

[a]Data as of August 2017; includes data for histiocytic, lymphocytic, mixed, unspecified, or undifferentiated cell types.

Table B-4. Summary of the Incidence of Non-neoplastic Lesions in Female Mice Exposed to GSM-modulated Cell Phone RFR for Two Years[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Disposition Summary				
Animals initially in study	105	105	105	105
14-week interim evaluation	15	15	15	15
Early deaths				
Moribund	9	9	9	6
Natural deaths	14	7	11	11
Survivors				
Died last week of study	1	4	2	1
Terminal euthanasia	66	70	68	72
Animals examined microscopically	100	100	100	100
14-week Interim Evaluation				
Alimentary System				
Liver	(10)	(10)	(10)	(9)
Inflammation, focal	1 (10%)	2 (20%)	4 (40%)	3 (33%)
Necrosis	–	1 (10%)	–	–
Salivary glands	(10)	(10)	(10)	(9)
Infiltration cellular, lymphocyte	–	–	3 (30%)	–
Stomach, glandular	(10)	(10)	(10)	(9)
Infiltration cellular, mixed cell	–	1 (10)%	–	–
Endocrine System				
Thyroid gland	(10)	(10)	(10)	(9)
Infiltration cellular, lymphocyte	1 (10%)	–	–	–
Hematopoietic System				
Thymus	(10)	(10)	(10)	(9)
Hemorrhage	–	2 (20%)	3 (30%)	–
Integumentary System				
Skin	(10)	(10)	(10)	(9)
Hair follicle, inflammation, chronic active	–	–	–	1 (11%)
Nervous System				
Spinal cord	(10)	(10)	(10)	(10)
Cyst, squamous, multiple	–	–	–	1 (10%)
Respiratory System				
Lung	(10)	(10)	(10)	(9)
Hemorrhage	–	1 (10%)	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Special Senses System				
Harderian gland	(10)	(10)	(10)	(9)
Infiltration cellular, lymphocyte	–	–	–	1 (11%)
Urinary System				
Kidney	(10)	(10)	(10)	(10)
Nephropathy, chronic progressive	–	1 (10%)	–	–
Interstitium, infiltration cellular, lymphocyte	–	–	3 (30%)	–
Urinary bladder	(10)	(10)	(10)	(9)
Infiltration cellular, lymphocyte	–	–	–	1 (11%)
Systems Examined with No Lesions Observed				
Cardiovascular System				
General Body System				
Genital System				
Musculoskeletal System				
Two-year Study				
Alimentary System				
Esophagus	(87)	(90)	(87)	(90)
Gallbladder	(79)	(75)	(74)	(72)
Cyst	–	1 (1%)	1 (1%)	–
Infiltration cellular, lymphocyte	2 (3%)	5 (7%)	2 (3%)	4 (6%)
Intestine large, cecum	(84)	(82)	(83)	(82)
Intestine large, colon	(84)	(84)	(86)	(85)
Intestine large, rectum	(88)	(86)	(88)	(86)
Intestine small, duodenum	(82)	(83)	(84)	(81)
Inflammation, acute	1 (1%)	–	–	–
Intestine small, ileum	(83)	(82)	(82)	(80)
Peyer’s patch, hyperplasia, lymphoid	–	–	1 (1%)	–
Intestine small, jejunum	(84)	(81)	(81)	(80)
Peyer’s patch, hyperplasia, lymphoid	1 (1%)	1 (1%)	–	–
Liver	(89)	(90)	(90)	(89)
Basophilic focus	4 (4%)	2 (2%)	5 (6%)	5 (6%)
Clear cell focus	1 (1%)	–	–	–
Eosinophilic focus	2 (2%)	1 (1%)	1 (1%)	–
Extramedullary hematopoiesis	1 (1%)	–	1 (1%)	–
Fatty change	7 (8%)	1 (1%)	–	2 (2%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Hemorrhage	1 (1%)	1 (1%)	1 (1%)	–
Infiltration cellular, lymphocyte	33 (37%)	25 (28%)	21 (23%)	32 (36%)
Infiltration cellular, mononuclear cell	1 (1%)	2 (2%)	1 (1%)	–
Infiltration cellular, polymorphonuclear	–	1 (1%)	–	–
Inflammation, focal	4 (4%)	2 (2%)	–	–
Inflammation, acute	–	–	1 (1%)	–
Inflammation, chronic active	1 (1%)	–	–	–
Mixed cell focus	5 (6%)	1 (1%)	–	1 (1%)
Necrosis	6 (7%)	5 (6%)	6 (7%)	3 (3%)
Artery, inflammation, chronic	–	–	1 (1%)	–
Bile duct, cyst	–	1 (1%)	1 (1%)	–
Centrilobular, hepatocyte, hypertrophy	–	–	–	1 (1%)
Hepatocyte, fatty change, focal	3 (3%)	–	1 (1%)	–
Hepatocyte, hyperplasia	–	–	1 (1%)	–
Hepatocyte, hypertrophy	–	–	1 (1%)	–
Hepatocyte, inclusion body intracytoplasmic	–	–	–	1 (1%)
Hepatocyte, vacuolization cytoplasmic	–	–	4 (4%)	1 (1%)
Kupffer cell, hyperplasia	1 (1%)	–	–	–
Mesentery	(29)	(24)	(32)	(30)
Artery, inflammation, chronic	–	2 (8%)	–	–
Fat, infiltration cellular, lymphocyte	2 (7%)	1 (4%)	–	–
Fat, inflammation, granulomatous	–	1 (4%)	–	–
Fat, inflammation, chronic active	1 (3%)	–	–	–
Fat, mineral	–	1 (4%)	1 (3%)	–
Fat, necrosis	25 (86%)	19 (79%)	27 (84%)	27 (90%)
Oral mucosa	(0)	(0)	(2)	(0)
Pancreas	(87)	(88)	(89)	(86)
Degeneration	–	–	–	1 (1%)
Infiltration cellular, lipocyte	–	1 (1%)	–	1 (1%)
Infiltration cellular, histiocyte	–	–	1 (1%)	–
Infiltration cellular, lymphocyte	27 (31%)	26 (30%)	30 (34%)	24 (28%)
Inflammation, suppurative	–	–	–	1 (1%)
Inflammation, chronic active	1 (1%)	–	–	–
Necrosis	–	–	–	1 (1%)
Acinus, atrophy	–	–	2 (2%)	1 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Duct, cyst	1 (1%)	1 (1%)	2 (2%)	3 (3%)
Duct, inflammation, chronic active	–	–	–	1 (1%)
Salivary glands	(89)	(89)	(90)	(90)
Atrophy	1 (1%)	–	–	–
Infiltration cellular, lymphocyte	59 (66%)	54 (61%)	55 (61%)	62 (69%)
Inflammation, acute	–	1 (1%)	–	–
Mineral	–	–	1 (1%)	–
Arteriole, inflammation, chronic	–	1 (1%)	–	–
Stomach, forestomach	(86)	(89)	(90)	(85)
Cyst	–	–	1 (1%)	–
Hyperkeratosis	–	–	1 (1%)	–
Ulcer	–	1 (1%)	–	–
Epithelium, hyperplasia, focal	–	–	2 (2%)	–
Stomach, glandular	(85)	(87)	(85)	(85)
Cyst	3 (4%)	3 (3%)	4 (5%)	–
Infiltration cellular, lymphocyte	–	–	1 (1%)	2 (2%)
Ulcer	–	–	1 (1%)	–
Tongue	(0)	(0)	(1)	(0)
Tooth	(0)	(0)	(1)	(0)
Cardiovascular System				
Aorta	(84)	(88)	(90)	(89)
Degeneration	–	–	–	1 (1%)
Inflammation, chronic active	1 (1%)	–	–	–
Blood vessel	(0)	(0)	(2)	(0)
Heart	(90)	(90)	(90)	(90)
Bacteria	1 (1%)	1 (1%)	2 (2%)	–
Cardiomyopathy	3 (3%)	1 (1%)	3 (3%)	3 (3%)
Thrombus	3 (3%)	1 (1%)	2 (2%)	–
Artery, inflammation, chronic active	–	4 (4%)	–	1 (1%)
Endocardium, hyperplasia	–	–	1 (1%)	–
Epicardium, infiltration cellular, mixed cell	1 (1%)	–	–	–
Epicardium, infiltration cellular, mononuclear cell	1 (1%)	–	–	–
Myocardium, fibrosis	1 (1%)	–	–	–
Myocardium, infiltration cellular, lymphocyte	–	–	1 (1%)	2 (2%)
Myocardium, inflammation, acute	–	1 (1%)	2 (2%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Myocardium, inflammation, chronic active	1 (1%)	–	–	–
Myocardium, mineral	4 (4%)	–	–	1 (1%)
Valve, hemorrhage	1 (1%)	–	–	–
Valve, infiltration cellular, lymphocyte	1 (1%)	–	–	–
Valve, inflammation, chronic	–	–	1 (1%)	–
Valve, thrombus	1 (1%)	–	–	–
Endocrine System				
Adrenal cortex	(84)	(88)	(90)	(90)
Accessory adrenal cortical nodule	–	1 (1%)	1 (1%)	1 (1%)
Angiectasis	1 (1%)	–	–	–
Hemorrhage	1 (1%)	–	3 (3%)	–
Mineral	1 (1%)	–	–	–
Vacuolization cytoplasmic	–	2 (2%)	–	–
Bilateral, extramedullary hematopoiesis	1 (1%)	–	–	–
Bilateral, hyperplasia, focal	–	1 (1%)	–	–
Bilateral, vacuolization cytoplasmic	–	3 (3%)	1 (1%)	1 (1%)
Subcapsular, hyperplasia	81 (96%)	85 (97%)	88 (98%)	86 (96%)
Adrenal medulla	(83)	(84)	(86)	(87)
Hemorrhage	2 (2%)	–	1 (1%)	–
Hyperplasia	–	–	2 (2%)	–
Mineral	1 (1%)	–	–	–
Islets, pancreatic	(87)	(88)	(90)	(86)
Hyperplasia	1 (1%)	3 (3%)	1 (1%)	–
Infiltration cellular, lymphocyte	3 (3%)	2 (2%)	2 (2%)	3 (3%)
Parathyroid gland	(60)	(57)	(64)	(62)
Cyst	1 (2%)	–	–	–
Infiltration cellular, lymphocyte	–	–	1 (2%)	1 (2%)
Pituitary gland	(80)	(80)	(84)	(84)
Pars distalis, angiectasis	2 (3%)	7 (9%)	6 (7%)	5 (6%)
Pars distalis, cyst	1 (1%)	3 (4%)	–	1 (1%)
Pars distalis, cytoplasmic alteration	–	–	–	1 (1%)
Pars distalis, hyperplasia, focal	2 (3%)	4 (5%)	5 (6%)	4 (5%)
Thyroid gland	(86)	(89)	(86)	(86)
Infiltration cellular, lymphocyte	1 (1%)	6 (7%)	6 (7%)	3 (3%)
Ultimobranchial cyst	–	–	2 (2%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Follicle, cyst	1 (1%)	1 (1%)	–	–
Follicular cell, hyperplasia, focal	–	4 (4%)	–	–
General Body System				
Peritoneum	(0)	(0)	(1)	(0)
Tissue NOS	(1)	(1)	(1)	(2)
Genital System				
Clitoral gland	(82)	(84)	(80)	(86)
Infiltration cellular, lymphocyte	3 (4%)	–	–	1 (1%)
Duct, cyst	1 (1%)	–	1 (1%)	–
Ovary	(75)	(86)	(82)	(80)
Angiectasis	–	1 (1%)	1 (1%)	2 (3%)
Cyst	9 (12%)	13 (15%)	8 (10%)	7 (9%)
Cyst, squamous	–	–	1 (1%)	–
Hemorrhage	1 (1%)	2 (2%)	1 (1%)	–
Hyperplasia, cystic, papillary	–	1 (1%)	1 (1%)	–
Hyperplasia, tubulostromal	–	–	–	1 (1%)
Infiltration cellular, lymphocyte	–	–	–	1 (1%)
Mineral	1 (1%)	–	–	–
Thrombus	–	–	1 (1%)	1 (1%)
Bursa, cyst	–	–	–	1 (1%)
Follicle, cyst	9 (12%)	11 (13%)	6 (7%)	7 (9%)
Granulosa cell, hyperplasia	–	2 (2%)	–	–
Paraovarian tissue, cyst	–	–	–	1 (1%)
Oviduct	(0)	(0)	(1)	(0)
Uterus	(89)	(90)	(90)	(89)
Angiectasis	1 (1%)	6 (7%)	5 (6%)	3 (3%)
Congestion	–	1 (1%)	–	–
Dilation	35 (39%)	29 (32%)	30 (33%)	26 (29%)
Hemorrhage	1 (1%)	1 (1%)	1 (1%)	–
Infiltration cellular, lymphocyte	–	–	1 (1%)	–
Inflammation, acute	–	1 (1%)	–	–
Thrombus	1 (1%)	–	–	–
Endometrium, cyst	3 (3%)	–	–	1 (1%)
Endometrium, hyperplasia	–	1 (1%)	–	1 (1%)
Endometrium, hyperplasia, cystic	68 (76%)	75 (83%)	72 (80%)	68 (76%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Endometrium, metaplasia, squamous	1 (1%)	–	–	–
Vagina	(0)	(0)	(1)	(0)
Hematopoietic System				
Bone marrow	(90)	(89)	(89)	(90)
Hypercellularity	7 (8%)	8 (9%)	4 (4%)	4 (4%)
Hypocellularity	1 (1%)	1 (1%)	–	–
Myeloid cell, hypercellularity	1 (1%)	–	–	–
Lymph node	(18)	(20)	(16)	(14)
Hemorrhage	–	–	1 (6%)	1 (7%)
Hyperplasia, lymphoid	1 (6%)	–	–	–
Axillary, infiltration cellular, mixed cell	1 (6%)	–	–	–
Axillary, pigment	1 (6%)	–	–	–
Bronchial, hyperplasia, lymphoid	2 (11%)	–	–	4 (29%)
Iliac, erythrophagocytosis	–	1 (5%)	–	–
Iliac, hemorrhage	1 (6%)	–	2 (13%)	–
Iliac, hyperplasia, lymphoid	4 (22%)	2 (10%)	6 (38%)	2 (14%)
Iliac, infiltration cellular, histiocyte	–	1 (5%)	1 (6%)	–
Iliac, infiltration cellular, mixed cell	1 (6%)	1 (5%)	4 (25%)	–
Iliac, pigment	–	–	4 (25%)	–
Lumbar, hyperplasia, lymphoid	–	1 (5%)	–	–
Lumbar, infiltration cellular, mixed cell	1 (6%)	–	–	–
Mediastinal, hyperplasia, lymphoid	1 (6%)	2 (10%)	–	–
Mediastinal, infiltration cellular, plasma cell	–	1 (5%)	–	–
Pancreatic, hyperplasia, lymphoid	1 (6%)	–	–	–
Renal, erythrophagocytosis	–	–	1 (6%)	–
Renal, hemorrhage	1 (6%)	–	–	–
Renal, hyperplasia, lymphoid	3 (17%)	2 (10%)	1 (6%)	–
Lymph node, mandibular	(76)	(77)	(81)	(83)
Hemorrhage	3 (4%)	2 (3%)	1 (1%)	1 (1%)
Hyperplasia, lymphoid	1 (1%)	1 (1%)	1 (1%)	4 (5%)
Infiltration cellular, histiocyte	–	–	2 (2%)	–
Infiltration cellular, mixed cell	1 (1%)	–	–	–
Lymph node, mesenteric	(71)	(84)	(80)	(83)
Angiectasis	–	1 (1%)	–	–
Erythrophagocytosis	1 (1%)	–	1 (1%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Hemorrhage	1 (1%)	4 (5%)	2 (3%)	1 (1%)
Hyperplasia, lymphoid	1 (1%)	10 (12%)	3 (4%)	3 (4%)
Infiltration cellular, histiocyte	3 (4%)	8 (10%)	6 (8%)	4 (5%)
Infiltration cellular, plasma cell	–	2 (2%)	–	–
Spleen	(86)	(87)	(89)	(87)
Atrophy	1 (1%)	–	–	–
Extramedullary hematopoiesis	20 (23%)	15 (17%)	19 (21%)	11 (13%)
Hyperplasia, lymphoid	11 (13%)	7 (8%)	13 (15%)	10 (11%)
Capsule, fibrosis	1 (1%)	–	–	–
Capsule, inflammation, chronic active	–	–	1 (1%)	–
Thymus	(85)	(80)	(84)	(86)
Atrophy	5 (6%)	3 (4%)	8 (10%)	1 (1%)
Cyst	2 (2%)	2 (3%)	7 (8%)	2 (2%)
Hemorrhage	–	–	1 (1%)	1 (1%)
Hyperplasia, lymphoid	1 (1%)	–	2 (2%)	2 (2%)
Infiltration cellular, histiocyte	–	1 (1%)	–	–
Integumentary System				
Mammary gland	(85)	(88)	(88)	(84)
Hyperplasia, focal	1 (1%)	–	1 (1%)	–
Hyperplasia, diffuse	1 (1%)	1 (1%)	1 (1%)	1 (1%)
Duct, dilation	1 (1%)	1 (1%)	2 (2%)	1 (1%)
Skin	(90)	(90)	(90)	(90)
Inflammation, chronic	–	1 (1%)	–	–
Ulcer	2 (2%)	2 (2%)	2 (2%)	2 (2%)
Epidermis, hyperplasia, multifocal	–	–	–	1 (1%)
Hair follicle, atrophy	2 (2%)	1 (1%)	4 (4%)	8 (9%)
Subcutaneous tissue, inflammation, chronic	–	–	1 (1%)	–
Musculoskeletal System				
Bone	(90)	(90)	(89)	(90)
Decreased bone	–	1 (1%)	–	–
Fibro-osseous lesion	11 (12%)	6 (7%)	4 (4%)	3 (3%)
Increased bone	–	1 (1%)	–	1 (1%)
Periosteum, vertebra, inflammation, granulomatous	–	1 (1%)	–	–
Skeletal muscle	(89)	(90)	(90)	(90)
Degeneration	–	–	2 (2%)	1 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Infiltration cellular, lymphocyte	16 (18%)	5 (6%)	10 (11%)	16 (18%)
Inflammation, chronic active	–	–	–	1 (1%)
Mineral	1 (1%)	–	–	–
Arteriole, inflammation, chronic	–	2 (2%)	–	–
Nervous System				
Brain	(87)	(90)	(90)	(90)
Cyst, squamous	–	–	2 (2%)	–
Hemorrhage	2 (2%)	–	3 (3%)	–
Hydrocephalus	1 (1%)	–	–	–
Inflammation, acute	1 (1%)	–	–	–
Inflammation, chronic	–	1 (1%)	–	–
Mineral	80 (92%)	78 (87%)	77 (86%)	78 (87%)
Necrosis	1 (1%)	1 (1%)	1 (1%)	1 (1%)
Artery, meninges, inflammation, chronic active	–	5 (6%)	3 (3%)	2 (2%)
Brain trigeminal ganglion	(75)	(74)	(80)	(79)
Nerve trigeminal	(56)	(58)	(53)	(35)
Peripheral nerve	(0)	(0)	(1)	(0)
Peripheral nerve, sciatic	(88)	(87)	(88)	(88)
Axon, degeneration	12 (14%)	6 (7%)	7 (8%)	6 (7%)
Spinal cord	(90)	(90)	(90)	(90)
Cyst, squamous	–	1 (1%)	–	–
Necrosis	–	3 (3%)	–	–
Artery, meninges, inflammation, chronic active	–	5 (6%)	1 (1%)	2 (2%)
Respiratory System				
Larynx	(0)	(0)	(2)	(0)
Lung	(90)	(90)	(90)	(90)
Congestion	–	2 (2%)	2 (2%)	1 (1%)
Hemorrhage	4 (4%)	1 (1%)	3 (3%)	3 (3%)
Hyperplasia, lymphoid	–	1 (1%)	1 (1%)	–
Infiltration cellular, histiocyte	1 (1%)	2 (2%)	–	–
Infiltration cellular, lymphocyte	3 (3%)	1 (1%)	2 (2%)	3 (3%)
Infiltration cellular, mononuclear cell	–	1 (1%)	–	–
Inflammation, acute	1 (1%)	–	–	–
Inflammation, chronic	1 (1%)	–	–	–
Inflammation, chronic active	–	–	–	1 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Alveolar epithelium, hyperplasia, focal	1 (1%)	1 (1%)	1 (1%)	3 (3%)
Serosa, inflammation, chronic	–	1 (1%)	–	–
Mediastinum	(2)	(0)	(0)	(0)
Nose	(89)	(90)	(90)	(90)
Inflammation, acute	1 (1%)	–	–	–
Respiratory epithelium, accumulation, hyaline droplet	–	1 (1%)	–	–
Respiratory epithelium, hyperplasia	–	–	1 (1%)	–
Vomeronasal organ, cyst	–	–	–	1 (1%)
Pleura	(0)	(0)	(1)	(0)
Trachea	(90)	(89)	(90)	(90)
Special Senses System				
Ear	(0)	(0)	(1)	(0)
Eye	(89)	(88)	(90)	(90)
Phthisis bulbi	–	–	1 (1%)	–
Anterior chamber, inflammation, acute	–	–	–	1 (1%)
Bilateral, retina, hemorrhage	–	–	1 (1%)	–
Cornea, inflammation, acute	–	–	1 (1%)	1 (1%)
Cornea, inflammation, chronic	–	–	2 (2%)	–
Cornea, inflammation, chronic active	–	1 (1%)	–	–
Cornea, necrosis	–	1 (1%)	1 (1%)	–
Harderian gland	(89)	(90)	(90)	(87)
Hyperplasia, focal	–	–	1 (1%)	–
Infiltration cellular, lymphocyte	58 (65%)	68 (76%)	69 (77%)	63 (72%)
Inflammation, chronic active	–	–	–	1 (1%)
Lacrimal gland	(0)	(1)	(2)	(0)
Zymbal’s gland	(0)	(0)	(1)	(0)
Urinary System				
Kidney	(89)	(87)	(89)	(88)
Cyst	1 (1%)	–	–	–
Glomerulopathy, hyaline	–	2 (2%)	–	–
Hemorrhage	–	–	–	1 (1%)
Infarct	14 (16%)	19 (22%)	20 (22%)	14 (16%)
Inflammation, acute	–	–	1 (1%)	–
Metaplasia, osseous	2 (2%)	2 (2%)	2 (2%)	2 (2%)
Nephropathy, chronic progressive	8 (9%)	15 (17%)	19 (21%)	14 (16%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Bilateral, infarct	1 (1%)	–	–	–
Interstitium, infiltration cellular, lymphocyte	63 (71%)	60 (69%)	65 (73%)	56 (64%)
Papilla, mineral	–	2 (2%)	1 (1%)	1 (1%)
Pelvis, dilatation	1 (1%)	–	–	–
Pelvis, mineral	–	–	–	1 (1%)
Pelvis, necrosis	–	–	1 (1%)	–
Renal tubule, dilation	1 (1%)	–	1 (1%)	1 (1%)
Renal tubule, hyaline droplet	–	1 (1%)	–	–
Renal tubule, mineral	1 (1%)	–	1 (1%)	–
Renal tubule, vacuolization cytoplasmic	–	1 (1%)	–	–
Ureter	(0)	(0)	(1)	(0)
Urethra	(0)	(0)	(1)	(0)
Urinary bladder	(86)	(87)	(86)	(86)
Angiectasis	–	–	–	2 (2%)
Infiltration cellular, lymphocyte	62 (72%)	67 (77%)	65 (76%)	68 (79%)
Inflammation, acute	–	–	1 (1%)	–
Arteriole, inflammation, chronic	–	1 (1%)	–	–
Urothelium, hyperplasia	–	–	1 (1%)	–

[a]Number of animals examined microscopically at the site and the number of animals with lesion.

Appendix C. Summary of Lesions in Male Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

Tables

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Table C-1. Summary of the Incidence of Neoplasms in Male Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Disposition Summary				
Animals initially in study	105	106	105	105
14-week interim evaluation	15	15	15	15
Early deaths				
Accidental death	–	–	1	–
Moribund	8	2	5	3
Natural deaths	16	6	13	16
Survivors				
Terminal euthanasia	66	83	71	71
Animals examined microscopically	100	101	100	100
Systems Examined at 14 Weeks with No Neoplasms Observed				
Alimentary System				
Cardiovascular System				
Endocrine System				
General Body System				
Genital System				
Hematopoietic System				
Integumentary System				
Musculoskeletal System				
Nervous System				
Respiratory System				
Special Senses System				
Urinary System				
Two-year Study				
Alimentary System				
Esophagus	(88)	(91)	(89)	(88)
Gallbladder	(73)	(80)	(75)	(76)
Intestine large, cecum	(81)	(87)	(81)	(80)
Adenoma	–	–	1(1%)	–
Intestine large, colon	(84)	(88)	(84)	(81)
Adenocarcinoma	–	–	1(1%)	–
Intestine large, rectum	(84)	(89)	(85)	(85)
Intestine small, duodenum	(77)	(86)	(81)	(80)
Adenocarcinoma	1(1%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Intestine small, ileum	(81)	(88)	(83)	(81)
Adenoma	–	–	–	1(1%)
Intestine small, jejunum	(79)	(87)	(81)	(82)
Adenocarcinoma	2(3%)	–	1(1%)	2(2%)
Adenoma	–	–	–	1(1%)
Hepatocellular carcinoma, metastatic, liver	1(1%)	–	–	–
Liver	(90)	(89)	(90)	(90)
Hemangiosarcoma	1(1%)	4(4%)	2(2%)	1(1%)
Hepatoblastoma	6(7%)	6(7%)	15(17%)	7(8%)
Hepatoblastoma, multiple	–	–	1(1%)	–
Hepatocellular adenoma	25(28%)	23(26%)	22(24%)	36(40%)
Hepatocellular adenoma, multiple	27(30%)	43(48%)	33(37%)	26(29%)
Hepatocellular carcinoma	26(29%)	13(15%)	18(20%)	24(27%)
Hepatocellular carcinoma, multiple	2(2%)	5(6%)	7(8%)	7(8%)
Hepatocholangiocarcinoma	1(1%)	–	–	2(2%)
Malignant fibrous histiocytoma, metastatic, skin	1(1%)	–	–	–
Sarcoma, metastatic, skeletal muscle	–	–	–	1(1%)
Mesentery	(12)	(9)	(18)	(16)
Hemangiosarcoma	1(8%)	–	–	–
Hepatoblastoma, metastatic, liver		–	1(6%)	–
Malignant fibrous histiocytoma, metastatic,skin	1(8%)	–	–	–
Fat, hepatocholangiocarcinoma, metastatic, liver	1(8%)	–	–	–
Fat, lipoma	1(8%)	–	2(11%)	–
Pancreas	(87)	(88)	(88)	(88)
Hepatocholangiocarcinoma, metastatic, liver	1(1%)	–	–	–
Salivary glands	(90)	(90)	(89)	(90)
Stomach, forestomach	(88)	(89)	(86)	(87)
Squamous cell papilloma	–	–	1(1%)	–
Stomach, glandular	(87)	(88)	(87)	(87)
Malignant fibrous histiocytoma, metastatic, skin	1(1%)	–	–	–
Tooth	(27)	(15)	(17)	(23)
Cardiovascular System				
Aorta	(89)	(88)	(90)	(89)
Alveolar/bronchiolar carcinoma, metastatic lung	1(1%)	–	–	–
Blood vessel	(1)	(1)	(0)	(0)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Heart	(90)	(91)	(90)	(90)
Alveolar/bronchiolar carcinoma, metastatic, lung	1(1%)	1(1%)	–	–
Hemangioma	–	1(1%)	–	–
Hepatocholangiocarcinoma, metastatic, liver	1(1%)	–	–	1(1%)
Sarcoma, metastatic, skeletal muscle	–	–	–	1(1%)
Endocrine System				
Adrenal cortex	(90)	(89)	(90)	(89)
Bilateral, malignant fibrous histiocytoma, metastatic, skin	1(1%)	–	–	–
Bilateral, subcapsular, adenoma	–	1(1%)	1(1%)	–
Subcapsular, adenoma	–	1(1%)	3(3%)	4(4%)
Subcapsular, carcinoma	–	–	1(1%)	–
Adrenal medulla	(90)	(89)	(88)	(89)
Pheochromocytoma benign	–	–	–	1(1%)
Islets, pancreatic	(88)	(90)	(89)	(89)
Adenoma	–	1(1%)	–	–
Carcinoma	–	1(1%)	–	–
Parathyroid gland	(68)	(57)	(66)	(65)
Pituitary gland	(86)	(84)	(89)	(83)
Pars distalis, adenoma	–	–	2(2%)	–
Pars distalis, carcinoma	–	–	1(1%)	–
Thyroid gland	(89)	(89)	(88)	(87)
Follicular cell, adenoma	–	1(1%)	1(1%)	1(1%)
General Body System				
Peritoneum	(1)	(0)	(0)	(0)
Hepatocholangiocarcinoma, metastatic, liver	1(100%)	–	–	–
Tissue NOS	(0)	(1)	(0)	(0)
Fat, hemangiosarcoma	–	1(100%)	–	–
Genital System				
Coagulating gland	(2)	(3)	(0)	(1)
Epididymis	(90)	(91)	(90)	(90)
Preputial gland	(89)	(89)	(89)	(89)
Prostate	(90)	(86)	(90)	(88)
Seminal vesicle	(90)	(90)	(90)	(90)
Fibroma	1(1%)	–	–	–
Malignant fibrous histiocytoma, metastatic, skin	1(1%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Testis	(90)	(91)	(88)	(90)
Interstitial cell, adenoma	2(2%)	2(2%)	–	–
Hematopoietic System				
Bone marrow	(90)	(90)	(90)	(90)
Hemangiosarcoma	–	–	1(1%)	–
Lymph node	(6)	(6)	(11)	(10)
Axillary, hepatocholangiocarcinoma metastatic, liver	1(17%)	–	–	–
Axillary, squamous cell carcinoma, metastatic, skin	–	–	1(9%)	–
Bronchial, sarcoma, metastatic, skeletal muscle	–	–	–	1(10%)
Lumbar, squamous cell carcinoma, metastatic, skin	–	–	1(9%)	–
Pancreatic, hepatoblastoma, metastatic, liver	–	–	1(9%)	–
Lymph node, mandibular	(72)	(70)	(63)	(64)
Lymph node, mesenteric	(85)	(88)	(86)	(85)
Hemangioma	1(1%)	–	–	–
Hepatoblastoma, metastatic, liver	–	–	1(1%)	–
Malignant fibrous histiocytoma, metastatic, skin	1(1%)	–	–	–
Spleen	(87)	(89)	(87)	(86)
Hemangiosarcoma	–	2(2%)	1(1%)	2(2%)
Thymus	(75)	(76)	(80)	(81)
Integumentary System				
Mammary gland	(2)	(1)	(0)	(3)
Skin	(90)	(91)	(90)	(90)
Lipoma	–	–	–	1(1%)
Pilomatrixoma	1(1%)	–	–	–
Squamous cell carcinoma	–	–	1(1%)	–
Squamous cell papilloma	–	–	–	1(1%)
Subcutaneous tissue, hemangiosarcoma	1(1%)	–	–	–
Subcutaneous tissue, lipoma	1(1%)	–	1(1%)	–
Subcutaneous tissue, malignant fibrous histiocytoma	1(1%)	1(1%)	2(2%)	–
Musculoskeletal System				
Bone	(90)	(91)	(90)	(90)
Skeletal muscle	(90)	(91)	(90)	(90)
Alveolar/bronchiolar carcinoma, metastatic, lung	–	1(1%)	1(1%)	–
Hepatoblastoma, metastatic, liver	–	–	1(1%)	–
Hepatocellular carcinoma, metastatic, liver	1(1%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Hepatocholangiocarcinoma, metastatic, liver	1(1%)	–	–	1(1%)
Malignant fibrous histiocytoma, metastatic, skin	1(1%)	–	–	–
Sarcoma	1(1%)	–	–	1(1%)
Squamous cell carcinoma, metastatic, skin	–	–	1(1%)	–
Nervous System				
Brain	(90)	(91)	(90)	(90)
Carcinoma, metastatic, pituitary gland	–	–	1(1%)	–
Hepatocholangiocarcinoma, metastatic, liver	1(1%)	–	–	–
Brain trigeminal ganglion	(69)	(79)	(80)	(80)
Nerve trigeminal	(67)	(57)	(43)	(55)
Peripheral nerve, sciatic	(89)	(91)	(87)	(88)
Spinal cord	(90)	(91)	(90)	(90)
Respiratory System				
Lung	(90)	(91)	(90)	(90)
Alveolar/bronchiolar adenoma	11(12%)	8(9%)	14(16%)	12(13%)
Alveolar/bronchiolar adenoma, multiple	2(2%)	–	2(2%)	–
Alveolar/bronchiolar carcinoma	11(12%)	13(14%)	11(12%)	11(12%)
Alveolar/bronchiolar carcinoma, multiple	2(2%)	–	–	–
Hepatoblastoma, metastatic, liver	1(1%)	–	2(2%)	–
Hepatocellular carcinoma, metastatic, liver	11(12%)	4(4%)	9(10%)	11(12%)
Hepatocholangiocarcinoma, metastatic, liver	1(1%)	–	–	1(1%)
Sarcoma, metastatic, skeletal muscle	–	–	–	1(1%)
Squamous cell carcinoma, metastatic, skin	–	–	1(1%)	–
Nose	(90)	(91)	(90)	(90)
Trachea	(90)	(90)	(90)	(89)
Special Senses System				
Eye	(90)	(91)	(89)	(90)
Harderian gland	(88)	(91)	(90)	(88)
Adenocarcinoma	3(3%)	3(3%)	1(1%)	2(2%)
Adenoma	6(7%)	4(4%)	4(4%)	4(5%)
Urinary System				
Kidney	(90)	(89)	(90)	(90)
Hepatocellular carcinoma, metastatic, liver	1(1%)	–	–	–
Hepatocholangiocarcinoma, metastatic, liver	1(1%)	–	–	–
Malignant fibrous histiocytoma, metastatic, skin	1(1%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Sarcoma, metastatic, skeletal muscle	–	–	–	1(1%)
Renal tubule, adenoma	–	–	–	1(1%)
Ureter	(0)	(0)	(1)	(0)
Urinary bladder	(87)	(90)	(90)	(89)
Systemic Lesions				
Multiple organs[b]	(90)	(91)	(90)	(90)
Histiocytic sarcoma	–	2(2%)	1(1%)	2(2%)
Leukemia granulocytic	–	–	–	1(1%)
Lymphoma malignant	6(7%)	3(3%)	5(6%)	4(4%)
Mast cell tumor	1(1%)	–	–	–
Neoplasm Summary				
Total animals with primary neoplasms[c]				
Two-year study	79	80	82	94
Total primary neoplasms				
Two-year study	144	139	157	155
Total animals with benign neoplasms				
Two-year study	61	70	63	70
Total benign neoplasms				
Two-year study	77	85	87	89
Total animals with malignant neoplasms				
Two-year study	49	42	58	50
Total malignant neoplasms				
Two-year study	66	54	70	66
Total animals with metastatic neoplasms				
Two-year study	14	6	14	13
Total metastatic neoplasms				
Two-year study	34	6	21	19
Total animals with uncertain neoplasms- benign or malignant				
Two-year study	1	–	–	–
Total uncertain neoplasms				
Two-year study	1	–	–	–

[a]Number of animals examined microscopically at the site and the number of animals with neoplasm.
[b]Number of animals with any tissue examined microscopically.
[c]Primary neoplasms: all neoplasms except metastatic neoplasms.

Table C-2. Statistical Analysis of Primary Neoplasms in Male Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Harderian Gland: Adenoma				
Overall rate[a]	6/90 (7%)	4/91 (4%)	4/90 (4%)	4/90 (4%)
Adjusted rate[b]	7.5%	4.6%	4.7%	4.8%
Terminal rate[c]	6/66 (9%)	4/83 (5%)	4/71 (6%)	3/71 (4%)
First incidence (days)	729 (T)	729 (T)	729 (T)	707
Poly-3 test[d]	P = 0.342N	P = 0.322N	P = 0.342N	P = 0.353N
Harderian Gland: Adenoma or Carcinoma				
Overall rate	9/90 (10%)	7/91 (8%)	5/90 (6%)	6/90 (7%)
Adjusted rate	11.2%	8.0%	5.9%	7.2%
Terminal rate	8/66 (12%)	7/83 (8%)	5/71 (7%)	5/71 (7%)
First incidence (days)	690	729 (T)	729 (T)	707
Poly-3 test	P = 0.237N	P = 0.331N	P = 0.176N	P = 0.273N
Liver: Hepatocellular Adenoma				
Overall rate	52/90 (58%)	66/89 (74%)	55/90 (61%)	62/90 (69%)
Adjusted rate	62.3%	75.4%	64.9%	72.7%
Terminal rate	45/66 (68%)	64/83 (77%)	51/71 (72%)	54/71 (76%)
First incidence (days)	393	625	656	478
Poly-3 test	P = 0.199	P = 0.043	P = 0.428	P = 0.096
Liver: Hepatocellular Carcinoma				
Overall rate	28/90 (31%)	18/89 (20%)	25/90 (28%)	31/90 (34%)
Adjusted rate	34.2%	20.6%	29.0%	36.2%
Terminal rate	18/66 (27%)	16/83 (19%)	18/71 (25%)	22/71 (31%)
First incidence (days)	608	629	559	461
Poly-3 test	P = 0.177	P = 0.033N	P = 0.287N	P = 0.459
Liver: Hepatocellular Adenoma or Carcinoma				
Overall rate	67/90 (74%)	70/89 (79%)	66/90 (73%)	73/90 (81%)
Adjusted rate	79.1%	79.6%	76.6%	83.3%
Terminal rate	51/66 (77%)	67/83 (81%)	58/71 (82%)	59/71 (83%)
First incidence (days)	393	625	559	461
Poly-3 test	P = 0.278	P = 0.543	P = 0.412N	P = 0.302
Liver: Hepatoblastoma				
Overall rate	6/90 (7%)	6/89 (7%)	16/90 (18%)	7/90 (8%)
Adjusted rate	7.5%	6.9%	18.9%	8.5%
Terminal rate	5/66 (8%)	6/83 (7%)	14/71 (20%)	7/71 (10%)
First incidence (days)	711	729 (T)	679	729 (T)
Poly-3 test	P = 0.328	P = 0.562N	P = 0.026	P = 0.523

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Liver: Hepatocellular Carcinoma or Hepatoblastoma				
Overall rate	32/90 (36%)	22/89 (25%)	37/90 (41%)	35/90 (39%)
Adjusted rate	39.1%	25.1%	42.8%	40.9%
Terminal rate	22/66 (33%)	20/83 (24%)	28/71 (39%)	26/71 (37%)
First incidence (days)	608	629	559	461
Poly-3 test	P = 0.159	P = 0.036N	P = 0.370	P = 0.472
Liver: Hepatocellular Adenoma, Hepatocellular Carcinoma, or Hepatoblastoma				
Overall rate	68/90 (76%)	70/89 (79%)	69/90 (77%)	75/90 (83%)
Adjusted rate	80.3%	79.6%	79.8%	85.6%
Terminal rate	52/66 (79%)	67/83 (81%)	59/71 (83%)	61/71 (86%)
First incidence (days)	393	625	559	461
Poly-3 test	P = 0.175	P = 0.532N	P = 0.548N	P = 0.230
Lung: Alveolar/bronchiolar Adenoma				
Overall rate	13/90 (14%)	8/91 (9%)	16/90 (18%)	12/90 (13%)
Adjusted rate	16.0%	9.1%	19.0%	14.4%
Terminal rate	9/66 (14%)	7/83 (8%)	15/71 (21%)	11/71 (16%)
First incidence (days)	488	594	727	585
Poly-3 test	P = 0.441	P = 0.131N	P = 0.382	P = 0.474N
Lung: Alveolar/bronchiolar Carcinoma				
Overall rate	13/90 (14%)	13/91 (14%)	11/90 (12%)	11/90 (12%)
Adjusted rate	16.1%	14.7%	12.9%	13.1%
Terminal rate	12/66 (18%)	10/83 (12%)	9/71 (13%)	8/71 (11%)
First incidence (days)	568	625	588	518
Poly-3 test	P = 0.326N	P = 0.486N	P = 0.360N	P = 0.375N
Lung: Alveolar/bronchiolar Adenoma or Carcinoma				
Overall rate	23/90 (26%)	21/91 (23%)	25/90 (28%)	21/90 (23%)
Adjusted rate	28.1%	23.7%	29.4%	24.9%
Terminal rate	18/66 (27%)	17/83 (21%)	22/71 (31%)	17/71 (24%)
First incidence (days)	488	594	588	518
Poly-3 test	P = 0.444N	P = 0.312N	P = 0.496	P = 0.385N
All Organs: Hemangiosarcoma				
Overall rate	2/90 (2%)	7/91 (8%)	4/90 (4%)	3/90 (3%)
Adjusted rate	2.5%	8.0%	4.7%	3.6%
Terminal rate	0/66 (0%)	7/83 (8%)	4/71 (6%)	3/71 (4%)
First incidence (days)	702	729 (T)	729 (T)	729 (T)
Poly-3 test	P = 0.483N	P = 0.107	P = 0.362	P = 0.513
All Organs: Hemangioma or Hemangiosarcoma				
Overall rate	3/90 (3%)	8/91 (9%)	4/90 (4%)	3/90 (3%)
Adjusted rate	3.7%	9.2%	4.7%	3.6%

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Terminal rate	1/66 (2%)	8/83 (10%)	4/71 (6%)	3/71 (4%)
First incidence (days)	702	729 (T)	729 (T)	729 (T)
Poly-3 test	P = 0.325N	P = 0.135	P = 0.526	P = 0.647N
All Organs: Malignant Lymphoma				
Overall rate	6/90 (7%)	3/91 (3%)	5/90 (6%)	4/90 (4%)
Adjusted rate	7.3%	3.4%	5.9%	4.8%
Terminal rate	4/66 (6%)	3/83 (4%)	3/71 (4%)	4/71 (6%)
First incidence (days)	263	729 (T)	674	729 (T)
Poly-3 test	P = 0.413N	P = 0.217N	P = 0.478N	P = 0.366N
All Organs: Benign Neoplasms				
Overall rate	61/90 (68%)	70/91 (77%)	63/90 (70%)	70/90 (78%)
Adjusted rate	72.4%	79.2%	73.8%	81.6%
Terminal rate	51/66 (77%)	67/83 (81%)	57/71 (80%)	61/71 (86%)
First incidence (days)	393	594	571	478
Poly-3 test	P = 0.134	P = 0.192	P = 0.487	P = 0.099
All Organs: Malignant Neoplasms				
Overall rate	49/90 (54%)	42/91 (46%)	58/90 (64%)	50/90 (56%)
Adjusted rate	57.6%	47.5%	66.4%	56.9%
Terminal rate	33/66 (50%)	38/83 (46%)	45/71 (63%)	36/71 (51%)
First incidence (days)	263	625	549	416
Poly-3 test	P = 0.320	P = 0.117N	P = 0.148	P = 0.524N
All Organs: Benign or Malignant Neoplasms				
Overall rate	79/90 (88%)	80/91 (88%)	82/90 (91%)	84/90 (93%)
Adjusted rate	90.2%	90.0%	93.3%	94.0%
Terminal rate	59/66 (89%)	75/83 (90%)	67/71 (94%)	67/71 (94%)
First incidence (days)	263	594	549	416
Poly-3 test	P = 0.159	P = 0.586N	P = 0.309	P = 0.251

T = terminal euthanasia.
[a]Number of neoplasm-bearing animals/number of animals examined. Denominator is number of animals examined microscopically for liver and lung; for other tissues, denominator is number of animals necropsied.
[b]Poly-3 estimated neoplasm incidence after adjustment for intercurrent mortality.
[c]Observed incidence at terminal euthanasia.
[d]Beneath the sham control incidence is the P value associated with the trend test. Beneath the exposed group incidence are the P values corresponding to pairwise comparisons between the sham controls and that exposed group. The Poly-3 test accounts for differential mortality in animals that do not reach terminal euthanasia. A negative trend or a lower incidence in an exposure group is indicated by **N**.

Table C-3. Historical Incidence of Liver Neoplasms in Control Male B6C3F1/N Mice[a]

Study (Study Start)	Hepatocellular Adenoma	Hepatocellular Carcinoma	Hepatoblastoma	Hepatocellular Adenoma, Hepatocellular Carcinoma, or Hepatoblastoma
Historical Incidence: All Studies				
Antimony trioxide (October 2008)	30/50	15/50	2/50	39/50
2,3-Butanedione (August 2009)	17/50	17/50	1/50	32/50
Green tea extract (July 2007)	35/50	15/50	2/50	40/50
2-Hydroxy-4-methoxybenzophenone (July 2010)	21/49	8/49	1/49	26/49
Indole-3-carbinol (April 2007)	26/50	12/50	3/50	36/50
CIMSTAR 3800 (May 2008)	24/50	11/50	0/50	32/50
Trim VX (August 2009)	23/50	21/50	0/50	34/50
p-Chloro-α,α,α-trifluorotoluene (January 2011)	25/50	8/50	1/50	31/50
Pentabromodiphenyl ether mixture [DE-71 (technical grade)] (February 2008)	23/50	18/50	1/50	31/50
Radiofrequency radiation (June 2012)	52/90	28/90	6/90	68/90
Tetrabromobisphenol A (August 2007)	32/50	11/50	2/50	39/50
Overall Historical Incidence				
Total (%)	308/589 (52.3%)	164/589 (27.8%)	19/589 (3.2%)	408/589 (69.3%)
Mean ± standard deviation	51.9% ± 10.3%	27.6% ± 8.3%	3.0% ± 2.2%	68.8% ± 8.6%
Range	34% - 70%	16% - 42%	0% - 7%	53% - 80%

[a]Data as of August 2017.

Table C-4. Summary of the Incidence of Non-neoplastic Lesions in Male MiceExposed to CDMA-modulated Cell Phone RFR for Two Years[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Disposition Summary				
Animals initially in study	105	106	105	105
14-week Interim Evaluation	15	15	15	15
Early deaths				
Accidental death	–	–	1	–
Moribund	8	2	5	3
Natural deaths	16	6	13	16
Survivors				
Terminal euthanasia	66	83	71	71
Animals examined microscopically	100	101	100	100
14-week Interim Evaluation				
Alimentary System				
Liver	(10)	(10)	(10)	(10)
Infiltration cellular, lymphocyte	–	–	1 (10%)	–
Infiltration cellular, mixed cell, multifocal	–	–	2 (20%)	–
Infiltration cellular, mixed cell	–	1 (10%)	–	–
Inflammation, focal	–	–	–	1 (10%)
Salivary glands	(10)	(10)	(10)	(10)
Infiltration cellular, lymphocyte	–	1 (10%)	–	–
Endocrine System				
Thyroid gland	(10)	(9)	(10)	(10)
Infiltration cellular, lymphocyte	–	–	–	1 (10%)
Hematopoietic System				
Lymph node, mandibular	(5)	(8)	(9)	(10)
Hemorrhage	–	–	1 (11%)	2 (20%)
Nervous System				
Brain	(10)	(10)	(10)	(10)
Hemorrhage	1 (10%)	–	–	–
Respiratory System				
Lung	(10)	(10)	(10)	(10)
Congestion	1 (10%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Hemorrhage	2 (20%)	–	–	–
Infiltration cellular, mixed cell	–	–	1 (10%)	–
Urinary System				
Kidney	(10)	(10)	(10)	(10)
Nephropathy, chronic progressive	1 (10%)	–	1 (10%)	1 (10%)
Interstitium, infiltration cellular, lymphocyte	2 (20%)	2 (20%)	3 (30%)	1 (10%)
Systems Examined with No Lesions Observed				
Cardiovascular System				
General Body System				
Genital System				
Integumentary System				
Musculoskeletal System				
Special Senses System				
Two-year Study				
Alimentary System				
Esophagus	(88)	(91)	(89)	(88)
Infiltration cellular, lymphocyte	–	1 (1%)	–	–
Gallbladder	(73)	(80)	(75)	(76)
Cyst	–	–	1 (1%)	–
Intestine large, cecum	(81)	(87)	(81)	(80)
Intestine large, colon	(84)	(88)	(84)	(81)
Intestine large, rectum	(84)	(89)	(85)	(85)
Intestine small, duodenum	(77)	(86)	(81)	(80)
Peyer’s patch, hyperplasia, lymphoid	–	–	–	1 (1%)
Intestine small, ileum	(81)	(88)	(83)	(81)
Peyer’s patch, hyperplasia, lymphoid	1 (1%)	1 (1%)	1 (1%)	3 (4%)
Peyer’s patch, infiltration cellular, plasma cell	1 (1%)	–	–	–
Intestine small, jejunum	(79)	(87)	(81)	(82)
Inflammation, granulomatous	1 (1%)	–	–	–
Epithelium, cyst	1 (1%)	–	–	–
Peyer’s patch, hyperplasia, lymphoid	–	1 (1%)	2 (2%)	3 (4%)
Peyer’s patch, infiltration, cellular, polymorphonuclear	–	1 (1%)	–	–
Serosa, inflammation, granulomatous	–	–	1 (1%)	–
Liver	(90)	(89)	(90)	(90)
Angiectasis	–	–	1 (1%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Basophilic focus	1 (1%)	2 (2%)	3 (3%)	2 (2%)
Clear cell focus	28 (31%)	49 (55%)	35 (39%)	31 (34%)
Congestion, chronic	–	1 (1%)	–	–
Eosinophilic focus	4 (4%)	5 (6%)	2 (2%)	5 (6%)
Extramedullary hematopoiesis	2 (2%)	–	1 (1%)	2 (2%)
Fatty change	37 (41%)	51 (57%)	26 (29%)	33 (37%)
Fibrosis	1 (1%)	–	–	–
Hemorrhage	1 (1%)	–	–	–
Infiltration cellular, lymphocyte	2 (2%)	–	1 (1%)	3 (3%)
Infiltration cellular, mixed cell	1 (1%)	1 (1%)	–	–
Infiltration cellular, polymorphonuclear	–	–	–	1 (1%)
Inflammation, focal	1 (1%)	1 (1%)	–	1 (1%)
Inflammation, chronic active	2 (2%)	–	1 (1%)	–
Metaplasia	–	–	–	1 (1%)
Mineral	–	–	–	1 (1%)
Mixed cell focus	2 (2%)	2 (2%)	3 (3%)	1 (1%)
Necrosis	6 (7%)	2 (2%)	9 (10%)	10 (11%)
Bile duct, cyst	–	–	–	1 (1%)
Capsule, fibrosis	–	1 (1%)	–	1 (1%)
Hepatocyte, degeneration	–	–	1 (1%)	–
Vein, inflammation, chronic active	–	1 (1%)	–	–
Mesentery	(12)	(9)	(18)	(16)
Artery, inflammation, chronic active	–	1 (11%)	–	1 (6%)
Artery, thrombus	–	–	–	1 (6%)
Fat, inflammation, granulomatous	–	–	1 (6%)	1 (6%)
Fat, necrosis	8 (67%)	8 (89%)	14 (78%)	12 (75%)
Pancreas	(87)	(88)	(88)	(88)
Hemorrhage	1 (1%)	–	–	–
Infiltration cellular, lymphocyte	3 (3%)	2 (2%)	2 (2%)	4 (5%)
Inflammation, granulomatous	1 (1%)	–	–	–
Artery, inflammation, chronic	–	1 (1%)	–	–
Duct, cyst	1 (1%)	–	–	1 (1%)
Duct, fibrosis	1 (1%)	–	–	
Salivary glands	(90)	(90)	(89)	(90)
Infiltration cellular, lymphocyte	58 (64%)	67 (74%)	68 (76%)	61 (68%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Stomach, forestomach	(88)	(89)	(86)	(87)
Cyst, squamous	–	1 (1%)	–	3 (3%)
Inflammation, acute	–	–	1 (1%)	–
Ulcer	–	–	–	1 (1%)
Epithelium, hyperplasia, focal	3 (3%)	–	3 (3%)	–
Epithelium, hyperplasia, diffuse	–	–	–	1 (1%)
Stomach, glandular	(87)	(88)	(87)	(87)
Hemorrhage	1 (1%)	–	–	–
Mineral	–	–	2 (2%)	–
Epithelium, hyperplasia, focal	1 (1%)	–	–	–
Tooth	(27)	(15)	(17)	(23)
Dysplasia	26 (96%)	15 (100%)	16 (94%)	22 (96%)
Inflammation, suppurative	2 (7%)	1 (7%)	–	–
Inflammation, chronic active	–	–	1 (6%)	2 (9%)
Cardiovascular System				
Aorta	(89)	(88)	(90)	(89)
Inflammation, chronic	–	1 (1%)	–	–
Blood vessel	(1)	(1)	(0)	(0)
Inflammation, chronic	1 (100%)	1 (100%)	–	–
Heart	(90)	(91)	(90)	(90)
Bacteria	1 (1%)	–	1 (1%)	–
Cardiomyopathy	1 (11%)	6 (7%)	6 (7%)	10 (11%)
Inflammation, acute	1 (1%)	–	1 (1%)	1 (1%)
Inflammation, chronic active	2 (2%)	–	1 (1%)	–
Mineral	–	–	–	1 (1%)
Thrombus	1 (1%)	1 (1%)	1 (1%)	–
Artery, inflammation, chronic active	1 (1%)	3 (3%)	1 (1%)	–
Endocardium, mineral	1 (1%)	–	–	–
Endothelium, hyperplasia	–	2 (2%)	–	1 (1%)
Epicardium, inflammation, chronic	1 (1%)	–	–	–
Epicardium, mineral	1 (1%)	–	–	–
Intima, vein, hyperplasia	–	2 (2%)	–	–
Myocardium, infiltration cellular, lymphocyte	–	2 (2%)	–	2 (2%)
Myocarcium, inflammation, chronic active	–	1 (1%)	–	–
Myocardium, mineral	2 (2%)	2 (2%)	–	1 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Myocardium, necrosis	1 (1%)	–	1 (1%)	–
Valve, inflammation, chronic active	–	1 (1%)	–	–
Vein, inflammation, chronic active	–	1 (1%)	–	–
Endocrine System				
Adrenal cortex	(90)	(89)	(90)	(89)
Accessory adrenal cortical nodule	1 (1%)	–	–	–
Angiectasis	1 (1%)	–	–	–
Hemorrhage	–	1 (1%)	–	–
Hyperplasia, focal	3 (3%)	3 (3%)	3 (3%)	1 (1%)
Hypertrophy, focal	2 (2%)	8 (9%)	–	3 (3%)
Vacuolization cytoplasmic, focal	–	1 (1%)	–	–
Bilateral, hyperplasia, focal	–	–	1 (1%)	–
Bilateral, hypertrophy, focal	1 (1%)	1 (1%)	–	1 (1%)
Subcapsular, hyperplasia	69 (77%)	73 (82%)	74 (82%)	66 (74%)
Adrenal medulla	(90)	(89)	(88)	(89)
Hyperplasia	–	1 (1%)	–	–
Islets, pancreatic	(88)	(90)	(89)	(89)
Hyperplasia	18 (20%)	13 (14%)	14 (16%)	11 (12%)
Infiltration cellular, lymphocyte	2 (2%)	1 (1%)	–	4 (4%)
Parathyroid gland	(68)	(57)	(66)	(65)
Cyst	–	1 (2%)	–	1 (2%)
Pituitary gland	(86)	(84)	(89)	(83)
Pars distalis, angiectasis	1 (1%)	–	–	–
Pars distalis, cyst	3 (3%)	1 (1%)	1 (1%)	2 (2%)
Pars distalis, hyperplasia, focal	1 (1%)	–	–	–
Thyroid gland	(89)	(89)	(88)	(87)
Infiltration cellular, lymphocyte	–	1 (1%)	1 (1%)	–
Arteriole, inflammation, chronic active	–	1 (1%)	–	–
Epithelium, follicle, hyperplasia, focal	–	1 (1%)	–	–
General Body System				
Peritoneum	(1)	(0)	(0)	(0)
Tissues NOS	(0)	(1)	(0)	(0)
Genital System				
Coagulating gland	(2)	(3)	(0)	(1)
Cyst	2 (100%)	3 (100%)	–	1 (100%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Infiltration cellular, lymphocyte	–	1 (33%)	–	–
Inflammation, chronic	–	1 (33%)	–	–
Epididymis	(90)	(91)	(90)	(90)
Granuloma sperm	1 (1%)	–	2 (2%)	–
Infiltration cellular, lymphocyte	29 (32%)	26 (29%)	26 (29%)	32 (36%)
Infiltration cellular, mononuclear cell	–	1 (1%)	–	–
Artery, inflammation, chronic	–	1 (1%)	1 (1%)	–
Preputial gland	(89)	(89)	(89)	(89)
Atrophy	–	1 (1%)	–	–
Infiltration cellular, lymphocyte	43 (48%)	40 (45%)	39 (44%)	38 (43%)
Inflammation, suppurative	1 (1%)	–	–	–
Inflammation, chronic active	1 (1%)	3 (3%)	3 (3%)	1 (1%)
Bilateral, inflammation, chronic active	–	–	–	1 (1%)
Bilateral, duct, dilation	6 (7%)	4 (4%)	5 (6%)	3 (3%)
Duct, dilation	10 (11%)	10 (11%)	5 (6%)	5 (6%)
Duct, inflammation, chronic active	–	–	–	1 (1%)
Duct, necrosis	1 (1%)	–	–	–
Prostate	(90)	(86)	(90)	(88)
Infiltration cellular, lymphocyte	4 (4%)	8 (9%)	10 (11%)	9 (10%)
Inflammation, acute	–	–	1 (1%)	–
Inflammation, chronic active	1 (1%)	–	–	–
Arteriole, inflammation, chronic	–	1 (1%)	–	–
Seminal vesicle	(90)	(90)	(90)	(90)
Dilation	4 (4%)	9 (10%)	4 (4%)	2 (2%)
Inflammation, chronic active	1 (1%)	–	–	1 (1%)
Bilateral, dilation	27 (30%)	19 (21%)	26 (29%)	14 (16%)
Testis	(90)	(91)	(88)	(90)
Bilateral, germinal epithelium, atrophy	–	–	1 (1%)	–
Germ cell, degeneration	2 (2%)	2 (2%)	4 (5%)	7 (8%)
Seminiferous tubule, necrosis	–	–	–	1 (1%)
Hematopoietic System				
Bone marrow	(90)	(90)	(90)	(90)
Hypercellularity	3 (3%)	–	2 (2%)	3 (3%)
Myeloid cell, hypercellularity	–	–	1 (1%)	–
Lymph node	(6)	(6)	(11)	(10)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Bronchial, hyperplasia, lymphoid	–	–	–	2 (20%)
Iliac, erythrophagocytosis	–	1 (17%)	–	–
Iliac, hemorrhage	–	–	1 (9%)	–
Iliac, hyperplasia, lymphoid	–	2 (33%)	4 (36%)	–
Iliac, infiltration cellular, histiocyte	–	–	–	1 (10%)
Iliac, pigment	–	–	2 (18%)	1 (10%)
Inguinal, hyperplasia, lymphoid	–	–	–	2 (20%)
Mediastinal, hyperplasia, lymphoid	–	2 (33%)	1 (9%)	2 (20%)
Renal, hemorrhage	1 (17%)	–	–	–
Renal, pigment	–	–	1 (9%)	–
Lymph node, mandibular	(72)	(70)	(63)	(64)
Hemorrhage	–	–	1 (2%)	1 (2%)
Hyperplasia, lymphoid	2 (3%)	–	1 (2%)	2 (3%)
Infiltration cellular, histiocyte	1 (1%)	1 (1%)	1 (2%)	2 (3%)
Infiltration cellular, plasma cell	–	1 (1%)	–	–
Lymph node, mesenteric	(85)	(88)	(86)	(85)
Erythrophagocytosis	1 (1%)	1 (1%)	1 (1%)	1 (1%)
Hemorrhage	10 (12%)	21 (24%)	16 (19%)	14 (16%)
Hyperplasia, lymphoid	4 (5%)	3 (3%)	5 (6%)	6 (7%)
Infiltration cellular, histiocyte	8 (9%)	7 (8%)	5 (6%)	5 (6%)
Infiltration cellular, mixed cell	–	–	1 (1%)	–
Infiltration cellular, plasma cell	1 (1%)	–	1 (1%)	–
Spleen	(87)	(89)	(87)	(86)
Extramedullary hematopoiesis	15 (17%)	7 (8%)	21 (24%)	16 (19%)
Hyperplasia, lymphoid	5 (6%)	4 (4%)	3 (3%)	9 (10%)
Thymus	(75)	(76)	(80)	(81)
Atrophy	11 (15%)	3 (4%)	8 (10%)	5 (6%)
Cyst	11 (15%)	17 (22%)	19 (24%)	19 (23%)
Hemorrhage	1 (1%)	–	–	1 (1%)
Hyperplasia, lymphoid	–	2 (3%)	–	–
Mammary gland	(2)	(1)	(0)	(3)
Skin	(90)	(91)	(90)	(90)
Infiltration cellular, mixed cell	1 (1%)	–	–	–
Inflammation, chronic	–	–	–	1 (1%)
Ulcer	2 (2%)	1 (1%)	2 (2%)	4 (4%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Epidermis, hyperplasia, focal	–	–	1 (1%)	2 (2%)
Musculoskeletal System				
Bone	(90)	(91)	(90)	(90)
Fibro-osseous lesion	–	–	1 (1%)	–
Increased bone	–	–	–	1 (1%)
Skeletal muscle	(90)	(91)	(90)	(90)
Degeneration	1 (1%)	1 (1%)	–	–
Infiltration cellular, lymphocyte	3 (3%)	1 (1%)	1 (1%)	4 (4%)
Inflammation, granulomatous	–	–	–	1 (1%)
Inflammation, acute	–	–	1 (1%)	–
Nervous System				
Brain	(90)	(91)	(90)	(90)
Hemorrhage	2 (2%)	–	–	–
Infiltration cellular, lymphocyte	1 (1%)	–	–	–
Mineral	79 (88%)	80 (88%)	77 (86%)	77 (86%)
Necrosis	–	1 (1%)	–	–
Artery, meninges, inflammation, chronic active	1 (1%)	2 (2%)	3 (3%)	1 (1%)
Meninges, inflammation, chronic	–	–	1 (1%)	–
Brain trigeminal ganglion	(69)	(79)	(80)	(80)
Nerve trigeminal	(67)	(57)	(43)	(55)
Peripheral nerve, sciatic	(89)	(91)	(87)	(88)
Inflammation, chronic active	–	–	–	1 (1%)
Axon, degeneration	9 (10%)	5 (5%)	4 (5%)	11 (13%)
Spinal cord	(90)	(91)	(90)	(90)
Degeneration	–	1 (1%)	–	–
Necrosis	1 (1%)	1 (1%)	1 (1%)	–
Squamous cyst	–	–	–	2 (2%)
Artery, meninges, inflammation, chronic active	1 (1%)	2 (2%)	4 (4%)	1 (1%)
Respiratory System				
Lung	(90)	(91)	(90)	(90)
Congestion	2 (2%)	–	3 (3%)	2 (2%)
Hemorrhage	3 (3%)	2 (2%)	4 (4%)	1 (1%)
Infiltration cellular, histiocyte	6 (7%)	5 (5%)	3 (3%)	5 (6%)
Infiltration cellular, lymphocyte	1 (1%)	1 (1%)	3 (3%)	–
Infiltration, mononuclear cell	–	–	1 (1%)	3 (3%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Inflammation, granulomatous	–	–	–	1 (1%)
Alveolar epithelium, hyperplasia, focal	6 (7%)	7 (8%)	8 (9%)	5 (6%)
Bronchiole, foreign body	1 (1%)	–	–	–
Bronchiole, inflammation, suppurative	1 (1%)	–	–	–
Nose	(90)	(91)	(90)	(90)
Infiltration cellular, lymphocyte	–	–	1 (1%)	–
Inflammation, acute	1 (1%)	–	–	–
Respiratory epithelium, accumulation, hyaline droplet	1 (1%)	–	–	1 (1%)
Respiratory epithelium, hyperplasia	5 (6%)	1 (1%)	–	–
Vomeronasal organ, fibrosis	1 (1%)	–	–	–
Trachea	(90)	(90)	(90)	(89)
Special Senses System				
Eye	(90)	(91)	(89)	(90)
Atrophy	–	–	1 (1%)	1 (1%)
Bilateral, cornea, inflammation, chronic active	–	–	–	1 (1%)
Bilateral, iris, synechia	–	–	–	1 (1%)
Cornea, edema	–	1 (1%)	–	–
Cornea, fibrosis	1 (1%)	–	–	–
Cornea, hyperplasia, squamous, diffuse	–	1 (1%)	–	–
Sclera, inflammation, acute	–	–	1 (1%)	–
Harderian gland	(88)	(91)	(90)	(88)
Hemorrhage	1 (1%)	–	–	–
Hyperplasia, focal	2 (2%)	3 (3%)	1 (1%)	–
Infiltration cellular, lymphocyte	36 (41%)	41 (45%)	40 (44%)	38 (43%)
Mineral	–	1 (1%)	–	–
Urinary System				
Kidney	(90)	(89)	(90)	(90)
Infarct	7 (8%)	6 (7%)	11 (12%)	7 (8%)
Inflammation, suppurative	1 (1%)	–	–	–
Inflammation, granulomatous	1 (1%)	–	–	–
Metaplasia, osseous	3 (3%)	8 (9%)	3 (3%)	5 (6%)
Mineral	–	3 (3%)	1 (1%)	1 (1%)
Nephropathy, chronic progressive	74 (82%)	84 (94%)	81 (90%)	77 (86%)
Artery, inflammation, chronic active	–	1 (1%)	–	–
Bilateral, bacteria	–	–	1 (1%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Bilateral, infarct	–	1 (1%)	–	2 (2%)
Bilateral, inflammation, acute	–	–	1 (1%)	–
Bilateral, renal tubule, pigment	–	–	–	1 (1%)
Glomerulus, cyst	1 (1%)	2 (2%)	–	1 (1%)
Interstitium, infiltration cellular, lymphocyte	41 (46%)	55 (62%)	57 (63%)	40 (44%)
Interstitium, inflammation, acute	–	–	–	1 (1%)
Papilla, bacteria	–	–	1 (1%)	–
Papilla, inflammation, acute	–	–	1 (1%)	–
Pelvis, dilation	1 (1%)	–	–	2 (2%)
Pelvis, inflammation, acute	–	–	–	1 (1%)
Renal tubule, cyst	8 (9%)	11 (12%)	7 (8%)	10 (11%)
Renal tubule, hyperplasia, focal	–	1 (1%)	–	–
Renal tubule, mineral	1 (1%)	4 (4%)	4 (4%)	5 (6%)
Urothelium, inflammation, chronic active	1 (1%)	–	–	–
Ureter	(0)	(0)	(1)	(0)
Inflammation, chronic active	–	–	1 (100%)	–
Urinary bladder	(87)	(90)	(90)	(89)
Hemorrhage	3 (3%)	–	–	–
Infiltration cellular, lymphocyte	26 (30%)	33 (37%)	39 (43%)	41 (46%)

[a]Number of animals examined microscopically at the site and the number of animals with lesion.

Appendix D. Summary of Lesions in Female Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

Tables

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Table D-1. Summary of the Incidence of Neoplasms in Female Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Disposition Summary				
Animals initially in study	105	104	105	105
14-week interim evaluation	15	15	15	15
Early deaths				
Moribund	9	5	4	4
Natural deaths	14	9	16	14
Survivors				
Died last week of study	1	3	1	1
Terminal euthanasia	66	72	69	71
Animals examined microscopically	100	99	100	100
Systems Examined at 14 Weeks with No Neoplasms Observed				
Alimentary System				
Cardiovascular System				
Endocrine System				
General Body System				
Genital System				
Hematopoietic System				
Integumentary System				
Musculoskeletal System				
Nervous System				
Respiratory System				
Special Senses System				
Urinary System				
Two-year Study				
Alimentary System				
Esophagus	(87)	(88)	(87)	(87)
Gallbladder	(79)	(75)	(72)	(73)
Intestine large, cecum	(84)	(82)	(80)	(81)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Intestine large, colon	(84)	(85)	(85)	(86)
Intestine large, rectum	(88)	(86)	(84)	(88)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Osteosarcoma, metastatic, skin	1 (1%)	–	–	–
Intestine small, duodenum	(82)	(81)	(80)	(77)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Intestine small, ileum	(83)	(82)	(76)	(81)
Intestine small, jejunum	(84)	(81)	(80)	(77)
Liver	(89)	(88)	(90)	(90)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Hemangiosarcoma	–	1 (1%)	–	–
Hepatoblastoma	1 (1%)	–	–	–
Hepatocellular adenoma	14 (16%)	20 (23%)	17 (19%)	13 (14%)
Hepatocellular adenoma, multiple	5 (6%)	4 (5%)	5 (6%)	7 (8%)
Hepatocellular carcinoma	6 (7%)	5 (6%)	3 (3%)	5 (6%)
Hepatocellular carcinoma, multiple	2 (2%)	–	2 (2%)	–
Hepatocholangiocarcinoma	–	–	1 (1%)	–
Osteosarcoma, metastatic, bone	1 (1%)	–	–	1 (1%)
Osteosarcoma, metastatic, brain	–	1 (1%)	–	–
Osteosarcoma, metastatic, skin	1 (1%)	–	–	–
Sarcoma, metastatic, skeletal muscle	–	1 (1%)	–	–
Mesentery	(29)	(24)	(34)	(24)
Fibrosarcoma, metastatic, skin	1 (3%)	–	–	–
Leiomyosarcoma, metastatic, uterus	–	–	–	1 (4%)
Renal mesenchymal tumor, metastatic, kidney	1 (3%)	–	–	–
Sarcoma, metastatic, skeletal muscle	–	1 (4%)	–	–
Fat, hemangioma	1 (3%)	–	–	–
Fat, lipoma	–	2 (8%)	1 (3%)	–
Pancreas	(87)	(86)	(85)	(84)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Leiomyosarcoma, metastatic, uterus	–	–	–	1 (1%)
Renal mesenchymal tumor, metastatic, kidney	1 (1%)	–	–	–
Acinus, adenoma	–	–	1 (1%)	–
Salivary glands	(89)	(88)	(87)	(89)
Stomach, forestomach	(86)	(88)	(87)	(87)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Leiomyosarcoma, metastatic, uterus	–	–	–	1 (1%)
Squamous cell papilloma	1 (1%)	1 (1%)	–	1 (1%)
Stomach, glandular	(85)	(88)	(85)	(83)
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Cardiovascular System				
Aorta	(84)	(87)	(89)	(90)
Heart	(90)	(89)	(90)	(90)
Osteosarcoma, metastatic, bone	–	–	1 (1%)	1 (1%)
Osteosarcoma, metastatic, skin	1 (1%)	–	–	–
Sarcoma, metastatic, skeletal muscle	–	1 (1%)	–	–
Endocrine System				
Adrenal cortex	(84)	(88)	(87)	(88)
Adenoma	1 (1%)	–	–	–
Adrenal medulla	(83)	(87)	(84)	(84)
Pheochromocytoma benign	–	–	–	1 (1%)
Pheochromocytoma malignant	2 (2%)	–	–	–
Bilateral, pheochromocytoma benign	–	–	1 (1%)	–
Islets, pancreatic	(87)	(88)	(89)	(87)
Adenoma	–	–	–	1 (1%)
Carcinoma	1 (1%)	–	–	–
Parathyroid gland	(60)	(59)	(65)	(68)
Pituitary gland	(80)	(79)	(88)	(86)
Pars distalis, adenoma	6 (8%)	8 (10%)	8 (9%)	1 (1%)
Pars distalis, carcinoma	–	–	–	1 (1%)
Pars distalis, fibrosarcoma, metastatic, skin	–	–	–	1 (1%)
Thyroid gland	(86)	(87)	(88)	(88)
C-cell carcinoma	1 (1%)	–	–	–
Follicular cell, adenoma	–	2 (2%)	1 (1%)	1 (1%)
General Body System				
Tissue NOS	(1)	(1)	(1)	(0)
Hemangiosarcoma	–	1 (100%)	–	–
Abdominal, osteosarcoma, metastatic, skin	1 (100%)	–	–	–
Genital System				
Clitoral gland	(82)	(82)	(81)	(82)
Ovary	(75)	(84)	(84)	(83)
Adenocarcinoma, metastatic, uterus	–	2 (2%)	–	–
Cystadenoma	2 (3%)	2 (2%)	6 (7%)	6 (7%)
Granulosa cell tumor benign	1 (1%)	–	–	–
Hemangioma	2 (3%)	–	–	1 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Luteoma	–	–	2 (2%)	1 (1%)
Teratoma benign	–	–	1 (1%)	–
Thecoma malignant	1 (1%)	–	–	–
Tubulostromal adenoma	–	–	1 (1%)	–
Uterus	(89)	(89)	(88)	(90)
Adenocarcinoma	–	2 (2%)	–	1 (1%)
Adenoma	–	–	1 (1%)	–
Fibroma	1 (1%)	–	–	–
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Granular cell tumor malignant	–	1 (1%)	–	–
Hemangiosarcoma	–	1 (1%)	–	1 (1%)
Leiomyoma	1 (1%)	–	–	
Leiomyosarcoma	–	1 (1%)	1 (1%)	2 (2%)
Polyp stromal	–	–	–	1 (1%)
Hematopoietic System				
Bone marrow	(90)	(89)	(89)	(89)
Hemangiosarcoma	–	–	1 (1%)	–
Lymph node	(18)	(21)	(18)	(18)
Bronchial, adenocarcinoma, metastatic, uterus	–	1 (5%)	–	–
Bronchial, alveolar/bronchiolar carcinoma metastatic, lung	1 (6%)	–	–	–
Bronchial, fibrosarcoma, metastatic, skin	1 (6%)	–	–	–
Iliac, hemangiosarcoma	–	1 (5%)	–	–
Lumbar, leiomyosarcoma, metastatic, uterus	–	–	–	1 (6%)
Pancreatic, adenocarcinoma, metastatic, uterus	–	1 (5%)	–	–
Lymph node, mandibular	(76)	(79)	(76)	(73)
Lymph node, mesenteric	(71)	(86)	(75)	(81)
Adenocarcinoma, metastatic, uterus	–	1 (1%)	–	–
Fibrosarcoma, metastatic, skin	1 (1%)	–	–	–
Hemangiosarcoma	–	1 (1%)		
Leiomyosarcoma, metastatic, uterus	–	–	–	1 (1%)
Renal mesenchymal tumor, metastatic, kidney	1 (1%)	–	–	–
Sarcoma, metastatic, skeletal muscle	–	1 (1%)	–	–
Spleen	(86)	(87)	(86)	(88)
Hemangiosarcoma	–	3 (3%)	2 (2%)	1 (1%)
Leiomyosarcoma, metastatic, uterus	–	–	–	1 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Thymus	(85)	(83)	(82)	(82)
Osteosarcoma, metastatic, bone	–	–	1 (1%)	–
Integumentary System				
Mammary gland	(85)	(87)	(90)	(88)
Adenocarcinoma	–	–	–	2 (2%)
Adenoma	–	1 (1%)	2 (2%)	–
Skin	(90)	(89)	(90)	(90)
Squamous cell carcinoma	–	–	–	1 (1%)
Subcutaneous tissue, fibroma	1 (1%)	–	–	–
Subcutaneous tissue, fibroma, multiple	–	–	–	1 (1%)
Subcutaneous tissue, fibrosarcoma	3 (3%)	1 (1%)	3 (3%)	2 (2%)
Subcutaneous tissue, fibrosarcoma, multiple	–	–	–	1 (1%)
Subcutaneous tissue, hemangioma	–	1 (1%)	–	–
Subcutaneous tissue, hemangiosarcoma	2 (2%)	–	–	1 (1%)
Subcutaneous tissue, lipoma	1 (1%)	–	–	–
Subcutaneous tissue, malignant fibrous histiocytoma	–	1 (1%)	1 (1%)	–
Subcutaneous tissue, osteosarcoma	1 (1%)	–	–	–
Subcutaneous tissue, sarcoma	2 (2%)	–	–	–
Musculoskeletal System				
Bone	(90)	(89)	(90)	(89)
Hemangioma	1 (1%)	–	–	–
Osteosarcoma	1 (1%)	2 (2%)	1 (1%)	2 (2%)
Skeletal muscle	(89)	(89)	(90)	(90)
Adenocarcinoma, metastatic, uterus	–	1 (1%)	–	–
Hemangiosarcoma	–	2 (2%)	–	–
Leiomyosarcoma, metastatic, uterus	–	–	–	1 (1%)
Osteosarcoma	1 (1%)	–	–	–
Sarcoma	–	1 (1%)	–	–
Nervous System				
Brain	(87)	(88)	(90)	(90)
Carcinoma, metastatic, pituitary gland	–	–	–	1 (1%)
Fibrosarcoma, metastatic, skin	–	–	–	1 (1%)
Osteosarcoma, metastatic, skeletal muscle	1 (1%)	–	–	–
Osteosarcoma, metastatic, uncertain primary site	–	1 (1%)	–	–
Brain trigeminal ganglion	(75)	(82)	(75)	(74)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Nerve trigeminal	(56)	(30)	(52)	(51)
Peripheral nerve, sciatic	(88)	(88)	(89)	(88)
Spinal cord	(90)	(89)	(90)	(90)
Osteosarcoma, metastatic, bone	–	–	–	1 (1%)
Respiratory System				
Lung	(90)	(89)	(90)	(90)
Alveolar/bronchiolar adenoma	3 (3%)	6 (7%)	4 (4%)	1 (1%)
Alveolar/bronchiolar adenoma, multiple	–	–	–	1 (1%)
Alveolar/bronchiolar carcinoma	3 (3%)	3 (3%)	3 (3%)	5 (6%)
Carcinoma, metastatic, thyroid gland	1 (1%)	–	–	–
Fibrosarcoma, metastatic, skin	1 (1%)	–	1 (1%)	–
Granular cell tumor malignant, metastatic, uterus	–	1 (1%)	–	–
Hepatocellular carcinoma, metastatic, liver	2 (2%)	–	1 (1%)	–
Osteosarcoma, metastatic, bone	1 (1%)	1 (1%)	1 (1%)	2 (2%)
Osteosarcoma, metastatic, brain	–	1 (1%)	–	–
Osteosarcoma, metastatic, skeletal muscle	1 (1%)	–	–	–
Osteosarcoma, metastatic, skin	1 (1%)	–	–	–
Sarcoma, metastatic, skeletal muscle	–	1 (1%)	–	–
Squamous cell carcinoma, metastatic, skin	–	–	–	1 (1%)
Mediastinum	(2)	(0)	(0)	(0)
Hepatocellular carcinoma, metastatic, liver	1 (50%)	–	–	–
Nose	(89)	(89)	(90)	(90)
Respiratory epithelium, adenoma	–	–	–	1 (1%)
Trachea	(90)	(87)	(89)	(88)
Special Senses System				
Eye	(89)	(89)	(90)	(89)
Harderian gland	(89)	(88)	(89)	(89)
Adenocarcinoma	–	1 (1%)	1 (1%)	2 (2%)
Adenoma	4 (4%)	8 (9%)	8 (9%)	4 (4%)
Urinary System				
Kidney	(89)	(89)	(88)	(87)
Adenocarcinoma, metastatic, uterus	–	1 (1%)	–	–
Renal mesenchymal tumor	1 (1%)	–	–	–
Renal tubule, adenoma	2 (2%)	–	–	–
Urinary bladder	(86)	(86)	(83)	(85)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Systemic Lesions				
Multiple organs[b]	(90)	(89)	(90)	(90)
Histiocytic sarcoma	8 (9%)	3 (3%)	2 (2%)	7 (8%)
Leukemia erythrocytic	–	1 (1%)	–	–
Leukemia granulocytic	–	–	2 (2%)	–
Lymphoma malignant	2 (2%)	9 (10%)	6 (7%)	7 (8%)
Neoplasm Summary				
Total animals with primary neoplasms[c]				
Two-year study	59	62	56	56
Total primary neoplasms				
Two-year study	85	96	88	83
Total animals with benign neoplasms				
Two-year study	36	42	43	32
Total benign neoplasms				
Two-year study	47	55	59	42
Total animals with malignant neoplasms				
Two-year study	33	32	26	36
Total malignant neoplasms				
Two-year study	38	41	29	41
Total animals with metastatic neoplasms				
Two-year study	9	6	3	6
Total metastatic neoplasms				
Two-year study	29	17	5	16
Total animals with malignant neoplasms of uncertain primary site				
Two-year study	–	1	–	–

[a]Number of animals examined microscopically at the site and the number of animals with neoplasm.
[b]Number of animals with any tissue examined microscopically.
[c]Primary neoplasms: all neoplasms except metastatic neoplasms.

Table D-2 Statistical Analysis of Primary Neoplasms in Female Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Harderian Gland: Adenoma				
Overall rate[a]	4/90 (4%)	8/89 (9%)	8/90 (9%)	4/90 (4%)
Adjusted rate[b]	5.0%	9.5%	9.6%	4.8%
Terminal rate[c]	4/67 (6%)	8/74 (11%)	7/69 (10%)	4/71 (6%)
First incidence (days)	739 (T)	739 (T)	704	739 (T)
Poly-3 test[d]	P = 0.415N	P = 0.208	P = 0.208	P = 0.621N
Harderian Gland: Adenoma or Carcinoma				
Overall rate	4/90 (4%)	9/89 (10%)	9/90 (10%)	6/90 (7%)
Adjusted rate	5.0%	10.7%	10.7%	7.2%
Terminal rate	4/67 (6%)	9/74 (12%)	8/69 (12%)	5/71 (7%)
First incidence (days)	739 (T)	739 (T)	704	653
Poly-3 test	P = 0.482	P = 0.143	P = 0.143	P = 0.397
Liver: Hepatocellular Adenoma				
Overall rate	19/89 (21%)[e]	24/88 (27%)	22/90 (24%)	20/90 (22%)
Adjusted rate	23.6%	28.8%	26.0%	24.1%
Terminal rate	17/67 (25%)	22/73 (30%)	17/69 (25%)	18/71 (25%)
First incidence (days)	511	579	644	679
Poly-3 test	P = 0.466N	P = 0.282	P = 0.429	P = 0.543
Liver: Hepatocellular Carcinoma				
Overall rate	8/89 (9%)	5/88 (6%)	5/90 (6%)	5/90 (6%)
Adjusted rate	10.0%	6.0%	6.0%	6.0%
Terminal rate	7/67 (10%)	3/73 (4%)	3/69 (4%)	5/71 (7%)
First incidence (days)	656	639	692	739 (T)
Poly-3 test	P = 0.255N	P = 0.255N	P = 0.251N	P = 0.259N
Liver: Hepatocellular Adenoma or Carcinoma				
Overall rate	25/89 (28%)	29/88 (33%)	26/90 (29%)	22/90 (24%)
Adjusted rate	30.9%	34.5%	30.6%	26.5%
Terminal rate	22/67 (33%)	25/73 (34%)	19/69 (28%)	20/71 (28%)
First incidence (days)	511	579	644	679
Poly-3 test	P = 0.217N	P = 0.371	P = 0.552N	P = 0.325N
Liver: Hepatocellular Carcinoma or Hepatoblastoma				
Overall rate	9/89 (10%)	5/88 (6%)	5/90 (6%)	5/90 (6%)
Adjusted rate	11.3%	6.0%	6.0%	6.0%
Terminal rate	8/67 (12%)	3/73 (4%)	3/69 (4%)	5/71 (7%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
First incidence (days)	656	639	692	739 (T)
Poly-3 test	P = 0.186N	P = 0.178N	P = 0.174N	P = 0.181N
Lung: Alveolar/bronchiolar Adenoma				
Overall rate	3/90 (3%)	6/89 (7%)	4/90 (4%)	2/90 (2%)
Adjusted rate	3.8%	7.2%	4.8%	2.4%
Terminal rate	3/67 (5%)	5/74 (7%)	4/69 (6%)	2/71 (3%)
First incidence (days)	739 (T)	738	739 (T)	739 (T)
Poly-3 test	P = 0.262N	P = 0.271	P = 0.525	P = 0.484N
Lung: Alveolar/bronchiolar Carcinoma				
Overall rate	3/90 (3%)	3/89 (3%)	3/90 (3%)	5/90 (6%)
Adjusted rate	3.7%	3.6%	3.6%	6.0%
Terminal rate	2/67 (3%)	3/74 (4%)	1/69 (1%)	4/71 (6%)
First incidence (days)	607	739 (T)	511	684
Poly-3 test	P = 0.270	P = 0.641N	P = 0.638N	P = 0.377
Lung: Alveolar/bronchiolar Adenoma or Carcinoma				
Overall rate	6/90 (7%)	9/89 (10%)	7/90 (8%)	6/90 (7%)
Adjusted rate	7.5%	10.7%	8.3%	7.2%
Terminal rate	5/67 (8%)	8/74 (11%)	5/69 (7%)	5/71 (7%)
First incidence (days)	607	738	511	684
Poly-3 test	P = 0.423N	P = 0.325	P = 0.536	P = 0.595N
Ovary: Cystadenoma				
Overall rate	2/75 (3%)	2/84 (2%)	6/84 (7%)	6/83 (7%)
Adjusted rate	3.0%	2.5%	7.6%	7.9%
Terminal rate	2/56 (4%)	2/70 (3%)	6/66 (9%)	5/65 (8%)
First incidence (days)	739 (T)	739 (T)	739 (T)	597
Poly-3 test	P = 0.077	P = 0.627N	P = 0.202	P = 0.189
Pituitary Gland (Pars Distalis): Adenoma				
Overall rate	6/80 (8%)	8/79 (10%)	8/88 (9%)	1/86 (1%)
Adjusted rate	8.4%	10.7%	9.8%	1.3%
Terminal rate	5/60 (8%)	8/67 (12%)	6/68 (9%)	1/68 (2%)
First incidence (days)	703	739 (T)	704	739 (T)
Poly-3 test	P = 0.029N	P = 0.430	P = 0.499	P = 0.043N
Pituitary Gland (Pars Distalis): Adenoma or Carcinoma				
Overall rate	6/80 (8%)	8/79 (10%)	8/88 (9%)	2/86 (2%)
Adjusted rate	8.4%	10.7%	9.8%	2.5%

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Terminal rate	5/60 (8%)	8/67 (12%)	6/68 (9%)	2/68 (3%)
First incidence (days)	703	739 (T)	704	739 (T)
Poly-3 test	P = 0.063N	P = 0.430	P = 0.499	P = 0.104N
Skin (Subcutaneous Tissue): Fibrosarcoma or Sarcoma				
Overall rate	5/90 (6%)	1/89 (1%)	3/90 (3%)	3/90 (3%)
Adjusted rate	6.2%	1.2%	3.6%	3.6%
Terminal rate	1/67 (2%)	0/74 (0%)	1/69 (1%)	2/71 (3%)
First incidence (days)	607	715	669	731
Poly-3 test	P = 0.422N	P = 0.097N	P = 0.338N	P = 0.346N
Skin (Subcutaneous Tissue): Fibroma, Fibrosarcoma, or Sarcoma				
Overall rate	6/90 (7%)	1/89 (1%)	3/90 (3%)	3/90 (3%)
Adjusted rate	7.4%	1.2%	3.6%	3.6%
Terminal rate	2/67 (3%)	0/74 (0%)	1/69 (1%)	2/71 (3%)
First incidence (days)	607	715	669	731
Poly-3 test	P = 0.301N	P = 0.054N	P = 0.228N	P = 0.235N
All Organs: Hemangiosarcoma				
Overall rate	2/90 (2%)	7/89 (8%)	2/90 (2%)	3/90 (3%)
Adjusted rate	2.5%	8.3%	2.4%	3.6%
Terminal rate	1/67 (2%)	4/74 (5%)	0/69 (0%)	2/71 (3%)
First incidence (days)	703	626	644	653
Poly-3 test	P = 0.436N	P = 0.098	P = 0.674N	P = 0.517
All Organs: Hemangioma or Hemangiosarcoma				
Overall rate	6/90 (7%)	8/89 (9%)	2/90 (2%)	4/90 (4%)
Adjusted rate	7.5%	9.5%	2.4%	4.8%
Terminal rate	5/67 (8%)	5/74 (7%)	0/69 (0%)	3/71 (4%)
First incidence (days)	703	626	644	653
Poly-3 test	P = 0.161N	P = 0.431	P = 0.122N	P = 0.349N
All Organs: Histiocytic Sarcoma				
Overall rate	8/90 (9%)	3/89 (3%)	2/90 (2%)	7/90 (8%)
Adjusted rate	9.7%	3.5%	2.4%	8.4%
Terminal rate	2/67 (3%)	1/74 (1%)	0/69 (0%)	5/71 (7%)
First incidence (days)	562	493	725	675
Poly-3 test	P = 0.558	P = 0.098N	P = 0.048N	P = 0.494N
All Organs: Malignant Lymphoma				
Overall rate	2/90 (2%)	9/89 (10%)	6/90 (7%)	7/90 (8%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Adjusted rate	2.5%	10.7%	7.2%	8.4%
Terminal rate	1/67 (2%)	8/74 (11%)	4/69 (6%)	4/71 (6%)
First incidence (days)	604	689	716	635
Poly-3 test	P = 0.220	P = 0.035	P = 0.152	P = 0.094
All Organs: Benign Neoplasms				
Overall rate	36/90 (40%)	42/89 (47%)	43/90 (48%)	32/90 (36%)
Adjusted rate	44.1%	49.7%	50.7%	38.3%
Terminal rate	32/67 (48%)	38/74 (51%)	34/69 (49%)	29/71 (41%)
First incidence (days)	511	579	644	597
Poly-3 test	P = 0.180N	P = 0.283	P = 0.240	P = 0.274N
All Organs: Malignant Neoplasms				
Overall rate	33/90 (37%)	33/89 (37%)	26/90 (29%)	36/90 (40%)
Adjusted rate	38.1%	37.9%	29.8%	41.6%
Terminal rate	17/67 (25%)	21/74 (28%)	12/69 (17%)	25/71 (35%)
First incidence (days)	448	493	499	484
Poly-3 test	P = 0.382	P = 0.552N	P = 0.160N	P = 0.379
All Organs: Benign or Malignant Neoplasms				
Overall rate	59/90 (66%)	62/89 (70%)	56/90 (62%)	56/90 (62%)
Adjusted rate	67.6%	71.3%	64.1%	64.1%
Terminal rate	42/67 (63%)	50/74 (68%)	40/69 (58%)	43/71 (61%)
First incidence (days)	448	493	499	484
Poly-3 test	P = 0.242N	P = 0.360	P = 0.366N	P = 0.371N

T = terminal euthanasia
[a]Number of neoplasm-bearing animals/number of animals examined. Denominator is number of animals examined microscopically for liver, lung, ovary, and pituitary gland; for other tissues, denominator is number of animals necropsied.
[b]Poly-3 estimated neoplasm incidence after adjustment for intercurrent mortality.
[c]Observed incidence at terminal euthanasia.
[d]Beneath the sham control incidence is the P value associated with the trend test. Beneath the exposed group incidence are the P values corresponding to pairwise comparisons between the sham controls and that exposed group. The Poly-3 test accounts for differential mortality in animals that do not reach terminal euthanasia. A negative trend or a lower incidence in an exposure group is indicated by **N**.
[e]A single incidence of hepatoblastoma occurred in an animal that also had an adenoma.

Table D-3. Historical Incidence of Malignant Lymphoma in Control Female B6C3F1/N Mice[a]

Study (Study Start)	Incidence in Controls
Historical Incidence: All Studies	
Antimony trioxide (October 2008)	7/50
2,3-Butanedione (August 2009)	9/50
Green tea extract (July 2007)	7/50
2-Hydroxy-4-methoxybenzophenone (July 2010)	5/50
Indole-3-carbinol (April 2007)	6/50
CIMSTAR 3800 (May 2008)	18/50
Trim VX (August 2009)	10/50
p-Chloro-α,α,α-trifluorotoluene (January 2011)	9/50
Pentabromodiphenyl ether mixture [DE-71 (technical grade)] (February 2008)	7/50
Radiofrequency radiation (June 2012)	2/90
Tetrabromobisphenol A (August 2007)	9/50
Overall Historical Incidence	
Total (%)	89/590 (15.1%)
Mean ± standard deviation	16.0% ± 8.3%
Range	2%-36%

[a]Data as of August 2017; includes data for histiocytic, lymphocytic, mixed, unspecified, or undifferentiated cell types.

Table D-4. Summary of the Incidence of Nonneoplastic Lesions in Female Mice Exposed to CDMA-modulated Cell Phone RFR for Two Years[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Disposition Summary				
Animals initially in study	105	104	105	105
14-week Interim Evaluation	15	15	15	15
Early deaths				
Moribund	9	5	4	4
Natural deaths	14	9	16	14
Survivors				
Died last week of study	1	3	1	1
Terminal euthanasia	66	72	69	71
Animals examined microscopically	100	99	100	100
14-week Interim Evaluation				
Alimentary System				
Liver	(10)	(10)	(10)	(10)
Inflammation, focal	1 (10%)	–	3 (30%)	2 (20%)
Necrosis, focal	–	–	1 (10%)	–
Endocrine System				
Thyroid gland	(10)	(10)	(10)	(10)
Infiltration cellular, lymphocyte	1 (10%)	–	–	–
Hematopoietic System				
Lymph node, mandibular	(8)	(8)	(9)	(10)
Hemorrhage	–	–	1 (11%)	–
Thymus	(10)	(10)	(10)	(10)
Hemorrhage	–	–	1 (10%)	2 (20%)
Nervous System				
Spinal cord	(10)	(10)	(10)	(10)
Cyst, squamous	–	1 (10%)	–	–
Respiratory System				
Lung	(10)	(10)	(10)	(10)
Hemorrhage	–	–	1 (10%)	–
Special Senses System				
Eye	(10)	(10)	(10)	(10)
Retina, dysplasia	–	1 (10%)	–	–
Urinary System				
Kidney	(10)	(10)	(10)	(10)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Nephropathy, chronic progressive	–	1 (10%)	–	–
Interstitium, infiltration cellular, lymphocyte	–	1 (10%)	1 (10%)	5 (50%)
Urinary bladder	(10)	(10)	(10)	(10)
Infiltration cellular, lymphocyte	–	–	1 (10%)	2 (20%)
Systems Examined with No Lesions Observed				
Cardiovascular System				
General Body System				
Genital System				
Integumentary System				
Musculoskeletal System				
Two-year Study				
Alimentary System				
Esophagus	(87)	(88)	(87)	(87)
Gallbladder	(79)	(75)	(72)	(73)
Cyst	–	–	1 (1%)	–
Infiltration cellular, lymphocyte	2 (3%)	4 (5%)	2 (3%)	3 (4%)
Epithelium, hyperplasia, diffuse	–	–	1 (1%)	–
Intestine large, cecum	(84)	(82)	(80)	(81)
Intestine large, colon	(84)	(85)	(85)	(86)
Intestine large, rectum	(88)	(86)	(84)	(88)
Intestine small, duodenum	(82)	(81)	(80)	(77)
Inflammation, acute	1 (1%)	–	–	–
Intestine small, ileum	(83)	(82)	(76)	(81)
Inflammation, suppurative	–	1 (1%)	–	–
Peyer’s patch, hyperplasia, lymphoid	–	2 (2%)	–	–
Intestine small, jejunum	(84)	(81)	(80)	(77)
Peyer’s patch, hyperplasia, lymphoid	1 (1%)	2 (2%)	–	–
Liver	(89)	(88)	(90)	(90)
Angiectasis	–	–	–	1 (1%)
Basophilic focus	4 (4%)	4 (5%)	3 (3%)	1 (1%)
Clear cell focus	1 (1%)	–	–	–
Eosinophilic focus	2 (2%)	–	2 (2%)	2 (2%)
Extramedullary hematopoiesis	1 (1%)	2 (2%)	–	2 (2%)
Fatty change	7 (8%)	1 (1%)	2 (2%)	9 (10%)
Hemorrhage	1 (1%)	–	1 (1%)	1 (1%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Infiltration cellular, lymphocyte	33 (37%)	22 (25%)	26 (29%)	24 (27%)
Infiltration cellular, mononuclear cell	1 (1%)	–	–	–
Inflammation, focal	4 (4%)	2 (2%)	–	–
Inflammation, chronic active	1 (1%)	–	–	2 (2%)
Mixed cell focus	5 (6%)	–	–	–
Necrosis	6 (7%)	2 (2%)	3 (3%)	4 (4%)
Centrilobular, necrosis	–	–	–	1 (1%)
Hepatocyte, fatty change, focal	3 (3%)	–	1 (1%)	–
Hepatocyte, hypertrophy	–	–	1 (1%)	–
Kupffer cell, hyperplasia	1 (1%)	–	–	–
Oval cell, hyperplasia	–	–	1 (1%)	–
Mesentery	(29)	(24)	(34)	(24)
Artery, inflammation, chronic	–	–	1 (3%)	–
Fat, infiltration cellular, lymphocyte	2 (7%)	–	1 (3%)	1 (4%)
Fat, inflammation, chronic	–	–	–	2 (8%)
Fat, inflammation, chronic active	1 (3%)	–	–	2 (8%)
Fat, mineral	–	1 (4%)	2 (6%)	–
Fat, necrosis	25 (86%)	22 (92%)	30 (88%)	19 (79%)
Pancreas	(87)	(86)	(85)	(84)
Infiltration cellular, lymphocyte	27 (31%)	23 (27%)	21 (25%)	19 (23%)
Inflammation, chronic active	1 (1%)	–	–	–
Necrosis	–	1 (1%)	–	2 (2%)
Acinus, atrophy	–	–	1 (1%)	2 (2%)
Duct, cyst	1 (1%)	–	3 (4%)	1 (1%)
Salivary glands	(89)	(88)	(87)	(89)
Atrophy	1 (1%)	–	–	–
Infiltration cellular, lymphocyte	59 (66%)	61 (69%)	54 (62%)	60 (67%)
Stomach, forestomach	(86)	(88)	(87)	(87)
Cyst	–	–	1 (1%)	–
Epithelium, hyperplasia, focal	–	–	1 (1%)	1 (1%)
Stomach, glandular	(85)	(88)	(85)	(83)
Cyst	3 (4%)	2 (2%)	–	–
Infiltration cellular, lymphocyte	–	–	2 (2%)	–
Cardiovascular System				
Aorta	(84)	(87)	(89)	(90)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Degeneration	–	–	1 (1%)	–
Inflammation, acute	–	–	1 (1%)	–
Inflammation, chronic active	1 (1%)	–	–	–
Thrombus	–	–	–	1 (1%)
Heart	(90)	(89)	(90)	(90)
Bacteria	1 (1%)	–	1 (1%)	2 (2%)
Cardiomyopathy	3 (3%)	4 (4%)	4 (4%)	6 (7%)
Thrombus	3 (3%)	–	–	2 (2%)
Artery, inflammation, chronic active	–	2 (2%)	1 (1%)	–
Endothelium, hyperplasia	–	1 (1%)	–	–
Epicardium, infiltration cellular, mixed cell	1 (1%)	–	–	–
Epicardium, infiltration cellular, mononuclear cell	1 (1%)	–	–	–
Myocardium, fibrosis	1 (1%)	–	–	1 (1%)
Myocardium, hemorrhage	–	1 (1%)	–	–
Myocardium, inflammation, acute	–	–	–	2 (2%)
Myocardium, inflammation, chronic active	1 (1%)	1 (1%)	2 (2%)	
Myocardium, mineral	4 (4%)	–	1 (1%)	2 (2%)
Myocardium, necrosis	–	–	1 (1%)	–
Valve, hemorrhage	1 (1%)	–	–	–
Valve, infiltration cellular, lymphocyte	1 (1%)	–	–	–
Valve, thrombus	1 (1%)	–	1 (1%)	–
Endocrine System				
Adrenal cortex	(84)	(88)	(87)	(88)
Accessory adrenal cortical nodule	–	–	2 (2%)	3 (3%)
Angiectasis	1 (1%)	–	–	–
Hemorrhage	1 (1%)	–	1 (1%)	1 (1%)
Hyperplasia, focal	–	1 (1%)	–	–
Infiltration cellular, mixed cell	–	–	1 (1%)	–
Mineral	1 (1%)	–	–	–
Vacuolization cytoplasmic	–	1 (1%)	–	–
Vacuolization cytoplasmic, focal	–	–	–	1 (1%)
Bilateral, extramedullary hematopoiesis	1 (1%)	–	–	–
Bilateral, infiltration cellular, mixed cell	–	–	1 (1%)	–
Bilateral, vacuolization cytoplasmic	–	1 (1%)	–	2 (2%)
Subcapsular, hyperplasia	81 (96%)	84 (95%)	84 (97%)	86 (98%)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Adrenal medulla	(83)	(87)	(84)	(84)
Hemorrhage	2 (2%)	–	–	–
Hyperplasia	–	2 (2%)	1 (1%)	–
Mineral	1 (1%)	–	–	–
Islets, pancreatic	(87)	(88)	(89)	(87)
Hyperplasia	1 (1%)	–	1 (1%)	2 (2%)
Infiltration cellular, lymphocyte	3 (3%)	3 (3%)	5 (6%)	1 (1%)
Parathyroid gland	(60)	(59)	(65)	(68)
Cyst	1 (2%)	–	–	–
Infiltration cellular, lymphocyte	–	1 (2%)	–	1 (1%)
Pituitary gland	(80)	(79)	(88)	(86)
Pars distalis, angiectasis	2 (3%)	9 (11%)	4 (5%)	2 (2%)
Pars distalis, cyst	1 (1%)	1 (1%)	1 (1%)	2 (2%)
Pars distalis, hyperplasia, focal	2 (3%)	2 (3%)	4 (5%)	6 (7%)
Thyroid gland	(86)	(87)	(88)	(88)
Infiltration cellular, lymphocyte	1 (1%)	1 (1%)	7 (8%)	5 (6%)
Inflammation, chronic active	–	1 (1%)	–	–
Follicle, cyst	1 (1%)	–	2 (2%)	3 (3%)
General Body System				
Tissue NOS	(1)	(1)	(1)	(0)
Genital System				
Clitoral gland	(82)	(82)	(81)	(82)
Infiltration cellular, lymphocyte	3 (4%)	–	–	1 (1%)
Inflammation, granulomatous	–	–	–	1 (1%)
Duct, cyst	1 (1%)	1 (1%)	–	–
Ovary	(75)	(84)	(84)	(83)
Angiectasis	–	3 (4%)	–	–
Cyst	9 (12%)	11 (13%)	7 (8%)	4 (5%)
Hemorrhage	1 (1%)	1 (1%)	–	–
Infiltration cellular, histiocyte	–	–	1 (1%)	–
Inflammation, granulomatous	–	–	–	1 (1%)
Mineral	1 (1%)	–	1 (1%)	–
Follicle, cyst	9 (12%)	7 (8%)	6 (7%)	8 (10%)
Granulosa cell, hyperplasia	–	–	–	1 (1%)
Paraovarian tissue, cyst	–	2 (2%)	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Uterus	(89)	(89)	(88)	(90)
Adenomyosis	–	–	1 (1%)	–
Angiectasis	1 (1%)	3 (3%)	3 (3%)	4 (4%)
Dilation	35 (39%)	21 (24%)	44 (50%)	37 (41%)
Hemorrhage	1 (1%)	–	–	–
Infiltration cellular, lymphocyte	–	–	–	1 (1%)
Inflammation, chronic active	–	–	1 (1%)	–
Mineral	–	–	1 (1%)	–
Necrosis	–	–	1 (1%)	–
Thrombus	1 (1%)	–	3 (3%)	1 (1%)
Arteriole, degeneration	–	–	1 (1%)	–
Endometrium, cyst	3 (3%)	–	–	2 (2%)
Endometrium, hyperplasia, cystic	68 (76%)	75 (84%)	67 (76%)	68 (76%)
Endometrium, metaplasia, squamous	1 (1%)	–	–	–
Hematopoietic System				
Bone marrow	(90)	(89)	(89)	(89)
Hypercellularity	7 (8%)	8 (9%)	3 (3%)	4 (4%)
Hypocellularity	1 (1%)	–	1 (1%)	–
Myeloid cell, hypercellularity	1 (1%)	1 (1%)	–	–
Lymph node	(18)	(21)	(18)	(18)
Hemorrhage	–	–	1 (6%)	–
Hyperplasia, lymphoid	1 (6%)	–	–	–
Infiltration cellular, mixed cell	–	–	–	1 (6%)
Axillary, infiltration cellular, mixed cell	1 (6%)	–	–	–
Axillary, pigment	1 (6%)	–	–	–
Bronchial, hemorrhage	–	–	1 (6%)	–
Bronchial, hyperplasia, lymphoid	2 (11%)	2 (10%)	–	1 (6%)
Bronchial, infiltration cellular, histiocyte	–	1 (5%)	–	–
Bronchial, infiltration cellular, mixed cell	–	1 (5%)	–	–
Iliac, hemorrhage	1 (6%)	–	3 (17%)	1 (6%)
Iliac, hyperplasia, lymphoid	4 (22%)	4 (19%)	9 (50%)	4 (22%)
Iliac, infiltration cellular, histiocyte	–	1 (5%)	1 (6%)	–
Iliac, infiltration cellular, mixed cell	1 (6%)	1 (5%)	1 (6%)	1 (6%)
Iliac, infiltration cellular, plasma cell	–	–	1 (6%)	–
Iliac, pigment	–	1 (5%)	2 (11%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Lumbar, hemorrhage	–	1 (5%)	–	–
Lumbar, hyperplasia, lymphoid	–	2 (10%)	1 (6%)	–
Lumbar, infiltration cellular, mixed cell	1 (6%)	–	–	–
Mediastinal, hyperplasia, lymphoid	1 (6%)	4 (19%)	1 (6%)	3 (17%)
Mediastinal, infiltration cellular, histiocyte	–	–	–	1 (6%)
Pancreatic, hyperplasia, lymphoid	1 (6%)	–	–	1 (6%)
Renal, ectasia	–	1 (5%)	–	–
Renal, hemorrhage	1 (6%)	–	–	–
Renal, hyperplasia, lymphoid	3 (17%)	–	2 (11%)	2 (11%)
Renal, infiltration cellular, mixed cell	–	1 (5%)	–	–
Lymph node, mandibular	(76)	(79)	(76)	(73)
Hemorrhage	3 (4%)	1 (1%)	1 (1%)	2 (3%)
Hyperplasia, lymphoid	1 (1%)	1 (1%)	1 (1%)	2 (3%)
Infiltration cellular, histiocyte	–	1 (1%)	1 (1%)	–
Infiltration cellular, mixed cell	1 (1%)	–	–	–
Lymph node, mesenteric	(71)	(86)	(75)	(81)
Ectasia	–	–	–	1 (1%)
Erythrophagocytosis	1 (1%)	–	–	–
Hemorrhage	1 (1%)	3 (3%)	6 (8%)	3 (4%)
Hyperplasia, lymphoid	1 (1%)	5 (6%)	4 (5%)	4 (5%)
Infiltration cellular, histiocyte	3 (4%)	4 (5%)	2 (3%)	4 (5%)
Infiltration cellular, plasma cell	–	–	1 (1%)	–
Spleen	(86)	(87)	(86)	(88)
Atrophy	1 (1%)	–	–	–
Extramedullary hematopoiesis	20 (23%)	18 (21%)	12 (14%)	16 (18%)
Hemorrhage	–	1 (1%)	–	–
Hyperplasia, lymphoid	11 (13%)	10 (11%)	12 (14%)	14 (16%)
Capsule, fibrosis	1 (1%)	–	1 (1%)	–
Thymus	(85)	(83)	(82)	(82)
Atrophy	5 (6%)	3 (4%)	4 (5%)	2 (2%)
Cyst	2 (2%)	4 (5%)	4 (5%)	6 (7%)
Hemorrhage	–	2 (2%)	1 (1%)	2 (2%)
Hyperplasia, lymphoid	1 (1%)	–	2 (2%)	–
Integumentary System				
Mammary gland	(85)	(87)	(90)	(88)

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Hyperplasia, focal	1 (1%)	–	1 (1%)	–
Hyperplasia, diffuse	1 (1%)	1 (1%)	–	–
Infiltration cellular, lymphocyte	–	1 (1%)	–	–
Duct, dilation	1 (1%)	2 (2%)	2 (2%)	2 (2%)
Skin	(90)	(89)	(90)	(90)
Ulcer	2 (2%)	3 (3%)	1 (1%)	1 (1%)
Epidermis, hyperplasia, focal	–	1 (1%)	–	1 (1%)
Hair follicle, atrophy	2 (2%)	2 (2%)	–	5 (6%)
Subcutaneous tissue, fibrosis	–	–	–	1 (1%)
Musculoskeletal System				
Bone	(90)	(89)	(90)	(89)
Fibro-osseous lesion	11 (12%)	–	1 (1%)	2 (2%)
Increased bone	–	1 (1%)	1 (1%)	–
Skeletal muscle	(89)	(89)	(90)	(90)
Degeneration	–	1 (1%)	–	1 (1%)
Infiltration cellular, lymphocyte	16 (18%)	7 (8%)	11 (12%)	9 (10%)
Mineral	1 (1%)	–	–	–
Nervous System				
Brain	(87)	(88)	(90)	(90)
Hemorrhage	2 (2%)	–	–	2 (2%)
Hydrocephalus	1 (1%)	–	–	–
Inflammation, acute	1 (1%)	–	–	–
Mineral	80 (92%)	81 (92%)	78 (87%)	74 (82%)
Necrosis	1 (1%)	–	1 (1%)	–
Artery, meninges, inflammation, chronic active	–	3 (3%)	1 (1%)	1 (1%)
Brain trigeminal ganglion	(75)	(82)	(75)	(74)
Nerve trigeminal	(56)	(30)	(52)	(51)
Peripheral nerve, sciatic	(88)	(88)	(89)	(88)
Axon, degeneration	12 (14%)	4 (5%)	8 (9%)	11 (13%)
Spinal cord	(90)	(89)	(90)	(90)
Cyst, squamous, multiple	–	–	1 (1%)	1 (1%)
Degeneration	–	1 (1%)	–	–
Demyelination	–	1 (1%)	–	–
Metaplasia, osseous	–	1 (1%)	–	–
Necrosis	–	2 (2%)	–	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Respiratory System				
Lung	(90)	(89)	(90)	(90)
Congestion	–	–	2 (2%)	4 (4%)
Hemorrhage	4 (4%)	7 (8%)	4 (4%)	4 (4%)
Infiltration cellular, histiocyte	1 (1%)	2 (2%)	1 (1%)	2 (2%)
Infiltration cellular, lymphocyte	3 (3%)	2 (2%)	4 (4%)	–
Infiltration cellular, mixed cell	–	1 (1%)	–	–
Infiltration cellular, mononuclear cell	–	1 (1%)	–	–
Inflammation, granulomatous	–	1 (1%)	–	–
Inflammation, acute	1 (1%)	–	–	–
Inflammation, chronic	1 (1%)	–	–	–
Inflammation, chronic active	–	–	–	1 (1%)
Alveolar epithelium, hyperplasia, focal	1 (1%)	3 (3%)	3 (3%)	3 (3%)
Mediastinum	(2)	(0)	(0)	(0)
Nose	(89)	(89)	(90)	(90)
Inflammation, acute	1 (1%)	–	–	–
Respiratoryepithelium, accumulation, hyaline droplet	–	–	1 (1%)	–
Trachea	(90)	(87)	(89)	(88)
Special Senses System				
Eye	(89)	(89)	(90)	(89)
Phthisis bulbi	–	–	–	1 (1%)
Anterior chamber, inflammation, acute	–	–	–	1 (1%)
Harderian gland	(89)	(88)	(89)	(89)
Hyperplasia, focal	–	1 (1%)	–	–
Infiltration cellular, lymphocyte	58 (65%)	66 (75%)	61 (69%)	64 (72%)
Urinary System				
Kidney	(89)	(89)	(88)	(87)
Cyst	1 (1%)	–	–	–
Infarct	14 (16%)	26 (29%)	23 (26%)	17 (20%)
Metaplasia, osseous	2 (2%)	1 (1%)	2 (2%)	2 (2%)
Nephropathy, chronic progressive	8 (9%)	12 (13%)	7 (8%)	7 (8%)
Bilateral, infarct	1 (1%)	–	–	–
Interstitium, infiltration cellular, lymphocyte	63 (71%)	65 (73%)	50 (57%)	50 (57%)
Medulla, mineral	–	–	–	1 (1%)
Papilla, mineral	–	–	2 (2%)	–

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Papilla, necrosis	–	1 (1%)	–	–
Pelvis, dilation	1 (1%)	–	–	–
Renal tubule, cyst	–	–	–	1 (1%)
Renal tubule, dilation	1 (1%)	–	1 (1%)	1 (1%)
Renal tubule, mineral	1 (1%)	–	–	–
Renal tubule, vacuolization cytoplasmic	–	–	1 (1%)	–
Urinary bladder	(86)	(86)	(83)	(85)
Angiectasis	–	–	6 (7%)	2 (2%)
Infiltration cellular, lymphocyte	62 (72%)	64 (74%)	70 (84%)	65 (76%)
Transitional epithelium, hyperplasia, diffuse	–	–	1 (1%)	–

[a]Number of animals examined microscopically at the site and the number of animals with lesion.

Appendix E. Genetic Toxicology

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E.1. Collection of Tissue Samples for Genotoxicity Testing

Exposures ceased at 7 a.m. on the day of necropsy at 14 weeks. Thirty-five male mice (five sham controls, 15 that were exposed to CDMA, and 15 that were exposed to GSM) were necropsied approximately 2 to 4 hours after cessation of exposure and 35 female mice (five sham controls, 15 that were exposed to CDMA, and 15 that were exposed to GSM) were necropsied approximately 5 to 7 hours after cessation of exposure. Animals were necropsied in the following order: one animal from each exposure group starting with the sham control group, moving through each of the exposed groups for each of the radio frequency modulations in turn, then rotating back to the sham control group; animals were necropsied in numerical order within each exposure group. Five different tissues (cerebrum, frontal cortex, hippocampus, liver, and blood leukocytes) were collected from each animal for the comet assay. Because blood was examined in both the micronucleus and the comet assays, a single tube of blood was collected per animal by retroorbital bleeding, and the sample was divided into two aliquots, one that was processed for the comet assay and the other for the micronucleus assay.

E.2. Comet Assay

For preparation of samples for the comet assay, a 50 µL sample of blood was transferred to a tube containing 1 mL of freshly prepared cold mincing buffer [Mg^{+2}, Ca^{+2}, and phenol free Hank's Balanced Salt Solution (Life Technologies, Carlsbad, CA) with 20 mM ethylenediaminetetraacetic acid (EDTA) pH 7.3 to 7.5 and 10% v/v fresh dimethyl sulfoxide (DMSO)]. The liver and the hippocampus, cerebellum, and frontal cortex sections of the brain were rinsed with cold mincing buffer to remove residual blood and held on ice briefly (≤5 minutes) until processed. Small portions (3 to 4 mm) of the left lobe of the liver and each brain section were placed in tubes containing cold mincing solution and rapidly minced until finely dispersed. All samples prepared for the comet assay were immediately flash frozen in liquid nitrogen[195] and subsequently transferred to a –80° C freezer for storage until shipment by overnight courier on dry ice to the analytical laboratory. Upon receipt, all samples were immediately placed in a –80° C freezer for storage until further processing.

Blood and tissue samples were thawed on ice and maintained on ice during slide preparation. Just prior to use, each cell suspension was shaken gently to mix the cells and placed back on ice for 15 to 30 seconds to allow clumps to settle. A portion of the supernatant was empirically diluted with 0.5% low melting point agarose (Lonza, Walkersville, MD) dissolved in Dulbecco's phosphate buffer (Ca^{+2}, Mg^{+2}, and phenol free) at 37° C and layered onto each well of a 2-well CometSlide™ (Trevigen, Gaithersburg, MD). Slides were immersed in cold lysing solution [2.5 M NaCl, 100 mM Na_2EDTA, 10 mM tris(hydroxymethyl)aminomethane (Tris), pH 10, containing freshly added 10% DMSO (Fisher Scientific, Pittsburgh, PA) and 1% Triton X-100] overnight in a refrigerator, protected from light. The following day, the slides were rinsed in 0.4 M Trizma base (pH 7.5), randomly placed onto the platform of a horizontal electrophoresis unit and treated with cold alkali solution (300 mM NaOH, 1 mM Na_2EDTA, pH>13) for 20 minutes to allow DNA unwinding, then electrophoresed at 4º to 9º C for 20 minutes at 25 V (0.7 V/cm), with a current of approximately 300 mA. Following electrophoresis, slides were neutralized with 0.4 M Trizma base (pH 7.5) for 5 minutes and then dehydrated by immersion in absolute ethanol (Pharmco-AAPER, Shelbyville, KY) for at least 5 minutes and allowed to air dry. Slides were prepared in a laboratory with a relative humidity no more than 60% and stored at room

temperature in a desiccator with a relative humidity of no more than 60% until stained and scored; stained slides were stored in a desiccator. NaCl, Na_2EDTA, Triton X-100, and Trizma base were purchased from Sigma-Aldrich (St. Louis, MO); NaOH was purchased from Fisher Scientific (Pittsburgh, PA).

After staining with SYBR® Gold (Molecular Probes, Life Technologies, Grand Island, NY), slides, independently coded to mask treatment, were scored using Comet Assay IV Imaging Software, Version 4.3.1 (Perceptive Instruments, Ltd., Suffolk, UK) validated for GLP Part 11 compliance. In the alkaline (pH>13) comet assay, when damaged nuclear DNA fragments, it undergoes unidirectional migration through the agarose gel within an electrical field, forming an image that resembles a comet, and the greater the amount of fragmentation, the greater the amount of DNA migration that will occur. The image analysis software partitions the intensity of the fluorescent signal of the DNA in the entire comet image into the percent that is attributable to the comet head and the percent attributable to the tail. Manual adjustment of the automated detection of head and tail features is sometimes required. To evaluate DNA damage levels, the extent of DNA migration was characterized for 100 scorable comet figures per animal/tissue as percent tail DNA (intensity of all tail pixels divided by the total intensity of all pixels in the comet, expressed as a percentage).

Comet figures are classified during the scoring process as scorable (evaluated for percent tail DNA), non-scorable (due to inability to evaluate percent tail DNA, e.g. if comets overlapped), and "hedgehog." Hedgehogs either have no defined head, i.e., all DNA appears to be in the tail, or the head and tail appear to be separated. Hedgehogs may represent cells that have sustained high levels of DNA damage and are apoptotic, although certain data suggest they may represent cells with high levels of repairable DNA damage[196; 197]. The frequency of hedgehogs (%HH) was determined by tabulating the number observed in a separate group of 100 cells per animal/tissue.

In Technical Report 595[198], in which the comet assay results in rats exposed to cell phone radio frequency radiation (RFR) are reported, it was noted that a marked interanimal variation in percent tail DNA and high %HH values were observed in some tissues, yet the range of percent tail DNA values appeared to be truncated at approximately 65%. To better understand these observations, rat slides were reanalyzed by scoring 150 cells/tissue per animal, as recommended by the OECD guideline[180]. In this rescoring of the rat samples, all scorable cells were included in the sample of 150 analyzed cells, regardless of the apparent level of DNA damage estimated by the scorer prior to software analysis of the images; highly damaged cells that were unscorable using the software (true HH) were not included. For the 150-cell scoring method, the %HH was not independently determined due to limitations at the time in the comet assay software arising from the added number of cells scored. Therefore, %HH was estimated by dividing the number of comets having greater than or equal to 90% tail DNA by 150.

Although far less interanimal variation was observed in mouse tissues compared to rat tissues, in an effort to maintain consistency in analyses across species, the mouse tissues that showed a clear response or a suggestion of a treatment-related effect were reevaluated using the same 150-cell approach that was used to reevaluate all of the rat tissues. These tissues included male mouse frontal cortex and female mouse liver and peripheral blood exposed to the CDMA and GSM modulations.

Although there was no concurrent positive control group in these cell phone RFR studies, slides were made with human TK6 cells treated with ethyl methanesulfonate (standard positive control compound for the comet assay) and were included in each electrophoresis run with each slide set as an internal technical positive control.

E.3. Micronucleus Assay

For the micronucleus assay, sampling schedules were as described for the comet assay. At 14 weeks, blood samples (approximately 200 µL) obtained by retroorbital bleeding (one sample per mouse) were placed into EDTA tubes and immediately refrigerated. The samples were sent on the day of collection to the analytical laboratory well insulated on cold packs via overnight delivery. Upon arrival, blood samples were diluted in anticoagulant (heparin) and fixed in ice cold methanol (Sigma-Aldrich; St. Louis, MO) according to instructions provided with the MicroFlowPLUS Kit (Litron Laboratories, Rochester, NY). Fixed blood samples were stored in a –80° C freezer for at least 3 days prior to analysis by flow cytometry.

Flow cytometric analysis of red blood cell samples was performed using MicroFlowPLUS Kit reagents and a FACSCalibur™ dual-laser bench top system (Becton Dickinson Biosciences, San Jose, CA) as described by Witt et al.[199]. Both mature [normochromatic erythrocytes (NCEs)] and immature [reticulocytes; polychromatic erythrocytes (PCEs)] erythrocytes were analyzed for the presence of micronuclei. Immature erythrocytes are distinguished by the presence of an active transferrin receptor (CD-71) on the cell surface. For each sample, 20,000 (± 2,000) immature CD71-positive erythrocytes were analyzed by flow cytometry to determine the frequency of micronucleated reticulocytes. Aggregates were excluded on the basis of forward and side scatter, platelets were excluded based on staining with an anti-CD61 antibody, and nucleated leukocytes were excluded on the basis of intense propidium iodide staining. Typically, more than one million NCEs (CD-71 negative) were enumerated concurrently during PCE analysis, allowing for calculation of the percentage of PCEs among total erythrocytes as a measure of bone marrow toxicity.

E.4. Data Analysis for the Comet and Micronucleus Assays

Data from both the comet and the micronucleus assays were analyzed using the same statistical methods[200]. Mean percent tail DNA was calculated for each cell type for each animal; likewise, mean micronucleated PCEs/1,000 PCEs and micronucleated NCEs/1,000 NCEs, as well as % PCEs, were calculated for each animal. These data are summarized in the tables as mean ± standard error of the mean. Levene's test was used to determine if variances among treatment groups were equal at $P = 0.05$. When variances were equal, linear regression analysis was used to test for linear trend and Williams' test was used to evaluate pairwise differences of each exposed group with the sham control group. When variances were unequal, nonparametric methods were used to analyze the data; Jonckheere's test was used to evaluate linear trend and Dunn's test was used to assess the significance of pairwise differences of each exposed group with the sham control group. To maintain the overall significance level at 0.05, the trend as well as the pairwise differences from the sham control group were declared statistically significant if $P<0.025$. A result was considered positive if the trend test was significant and if at least one exposed group was significantly elevated over the sham control group, or if two or more exposed groups were significantly increased over the corresponding sham control group. A response was considered

equivocal if only the trend test was significant or if only a single exposed group was significantly increased over the sham control.

E.5. Results

Twenty sets of tissues obtained from animals at the 14-week interim evaluation in the 2-year study were evaluated for DNA damage using the comet assay (two sexes, five tissues, two cell phone RFR modulations). Results are reported based on the 100-cell scoring approach that was the standard method in use at the time of the study. Data for some tissues obtained using a second, 150-cell scoring approach recommended by a recently adopted international guideline for the in vivo comet assay, are noted for comparison. Significant increases in DNA damage were observed in cells of the frontal cortex of male mice exposed to both modulations, CDMA and GSM (Table E-1, Table E-2). Positive results were also obtained for male mouse frontal cortex (CDMA and GSM) (Table E-3) using the 150-cell approach. Of note is the low percent tail DNA value in the frontal cortex of sham control mice. There is no appropriate historical control database to provide context for this response, but bonafide changes in DNA damage levels in a treatment group should remain constant relative to the control value. No technical aspects of the study that may have influenced this control value independently of the treated group values (e.g., % agarose gel, duration of electrophoresis, electromagnetic field strength, slide position in the electrophoresis tank) were identified. Technical factors that influence control levels have not been shown to alter sensitivity to detect effects in treated groups[193]. No other tissues showed evidence of a treatment-related effect in male mice. In female mice exposed to the CDMA modulation, significant increases in DNA damage were seen in blood leukocytes using both scoring approaches (Table E-4, Table E-6). In female mouse liver samples exposed to either modulation, the mean percent tail DNA was elevated above the sham control for all exposures when evaluated using either scoring approach. Results of the 100-cell scoring approach were judged to be negative (Table E-4, Table E-5); scoring 150 cells resulted in a negative call for GSM-exposed female mice (Table E-6) but in CDMA-exposed female mouse liver, significant increases ($P = 0.009$) in percent tail DNA were seen in the 5 and 10 W/kg groups, resulting in a positive call for this dataset.

In the micronucleus assay for male mice exposed to CDMA (Table E-7), although a significant trend was observed for micronucleated PCEs ($P = 0.013$), the absolute increase was quite small and fell within the laboratory's historical control range. In addition, no corresponding increase in micronucleated NCEs was observed; the mature erythrocyte population ought to be in steady state equilibrium after continuous 14 weeks of exposure, such as occurred in this study. Thus, the overall result in the micronucleus assay for male mice exposed to CDMA was judged to be negative. No other significant effects on either micronucleus frequency or % PCEs were seen in male or female mice exposed to either modulation of cell phone RFR.

Table E-1. DNA Damage in Male Mice Exposed to CDMA-modulated Cell Phone RFR for 14 Weeks (100-Cell Method)[a]

	Dose (W/kg)	Percent Tail DNA[b]	P Value[c]	Percent Hedgehogs[b]
Frontal Cortex				
Sham Control[d]	0	0.63 ± 0.08		0.40 ± 0.24
CDMA	2.5	3.46 ± 0.65	0.014	0.60 ± 0.40
	5	5.88 ± 1.06	0.001	0.60 ± 0.24
	10	8.85 ± 1.09	0.001	4.40 ± 1.69
		P = 0.001e		
Hippocampus				
Sham Control	0	7.69 ± 2.00		1.20 ± 0.58
CDMA	2.5	9.59 ± 4.33	0.521	5.40 ± 2.11
	5	6.44 ± 1.21	0.606	2.80 ± 0.97
	10	6.38 ± 0.93	0.641	4.40 ± 2.27
		P = 0.740		
Cerebellum				
Sham Control	0	5.48 ± 1.30		1.80 ± 0.80
CDMA	2.5	7.35 ± 2.47	0.339	4.40 ± 2.06
	5	7.87 ± 2.80	0.404	4.60 ± 2.34
	10	5.43 ± 2.43	0.431	1.60 ± 0.93
		P = 0.554		
Liver				
Sham Control	0	16.30 ± 2.21		6.80 ± 2.82
CDMA	2.5	20.27 ± 5.53	1.000	21.60 ± 16.88
	5	16.15 ± 1.15	1.000	11.00 ± 3.77
	10	16.43 ± 0.83	1.000	7.20 ± 1.11
		P = 0.368		
Peripheral Blood				
Sham Control	0	1.60 ± 0.68		0.40 ± 0.24
CDMA	2.5	2.10 ± 0.50	0.449	1.20 ± 0.58
	5	1.30 ± 0.28	0.527	0.40 ± 0.24
	10	2.86 ± 0.26	0.046	1.40 ± 0.87
		P = 0.057		

[a]Study was performed at ILS, Inc. The detailed protocol (100 cell) is presented by Recio et al.[195]. Groups of five mice per exposure group were 5 to 6 weeks old when exposure began.
[b]Mean ± standard error.
[c]Pairwise comparison with the sham control group; exposed group values are significant at P ≤ 0.025 by Williams' test.
[d]No exposure to CDMA-modulated cell phone RFR.
[e]Dose-related trend derived from one-tailed linear regression or Jonckheere's test; the trend is significant when P ≤ 0.025.

Table E-2. DNA Damage in Male Mice Exposed to GSM-modulated Cell Phone RFR for 14 Weeks (100-Cell Method)[a]

	Dose (W/kg)	Percent Tail DNA[b]	P Value[c]	Percent Hedgehogs[b]
Frontal Cortex				
Sham Controld	0	0.63 ± 0.08		0.40 ± 0.24
GSM	2.5	1.71 ± 0.46	0.081	1.80 ± 0.97
	5	1.39 ± 0.15	0.081	1.60 ± 0.81
	10	3.73 ± 0.65	0.001	1.00 ± 0.45
		P = 0.001e		
Hippocampus				
Sham Control	0	7.69 ± 2.00		1.20 ± 0.58
GSM	2.5	8.74 ± 1.93	0.514	5.40 ± 2.11
	5	7.17 ± 1.08	0.598	2.20 ± 0.97
	10	6.90 ± 1.19	0.633	5.40 ± 2.54
		P = 0.720		
Cerebellum				
Sham Control	0	5.48 ± 1.30		1.80 ± 0.80
GSM	2.5	3.66 ± 0.30	0.831	3.00 ± 1.38
	5	3.90 ± 0.59	0.896	1.80 ± 0.92
	10	3.85 ± 1.08	0.919	3.40 ± 1.50
		P = 0.838		
Liver				
Sham Control	0	16.30 ± 2.21		6.80 ± 2.82
GSM	2.5	17.66 ± 1.89	0.469	8.20 ± 3.84
	5	15.40 ± 1.20	0.549	6.60 ± 1.96
	10	18.94 ± 2.00	0.213	12.80 ± 4.40
		P = 0.198		
Peripheral Blood				
Sham Control	0	1.60 ± 0.68		0.40 ± 0.24
GSM	2.5	1.85 ± 0.96	0.416	1.20 ± 1.20
	5	1.75 ± 0.37	0.491	1.00 ± 0.55
	10	1.85 ± 0.24	0.494	0.80 ± 0.58
		P = 0.408		

[a]Study was performed at ILS, Inc. The detailed protocol (100 cell) is presented by Recio et al.[195]. Groups of five mice per exposure group were 5 to 6 weeks old when exposure began.
[b]Mean ±standard error
[c]Pairwise comparison with the sham control group; exposed group values are significant at P ≤ 0.025 by Williams' test.
[d]No exposure to GSM-modulated cell phone RFR
[e]Dose-related trend derived from one-tailed linear regression or Jonckheere's test; the trend is significant when P ≤ 0.025.

Table E-3. DNA Damage in the Frontal Cortex of Male Mice Exposed to CDMA- or GSM-modulated Cell Phone RFR for 14 Weeks (150-Cell Method)[a]

	Dose (W/kg)	Percent Tail DNA[b]	P Value[c]	Percent Hedgehogs[b,d]
Sham Control[e]	0	1.32 ± 0.21		0
CDMA	2.5	4.52 ± 0.57	0.131	0
	5	6.06 ± 0.96	0.018	0
	10	10.04 ± 2.08	0.001	0.53 ± 0.39
		P = 0.001[f]		
GSM	2.5	4.25 ± 1.20	0.063	0.13 ± 0.13
	5	3.69 ± 0.53	0.063	0
	10	5.60 ± 1.28	0.006	0.13 ± 0.13
		P = 0.004		

[a]Study was performed at ILS, Inc. The detailed protocol (150 cell) is presented by OECD[180]. Groups of five mice per exposure group were 5 to 6 weeks old when exposure began.
[b]Mean ± standard error.
[c]Pairwise comparison with the sham control group; exposed group values are significant at P ≤ 0.025 by Williams' test.
[d]Percent hedgehogs=estimated as the number of comets with ≥90% tail DNA/150.
[e]No exposure to CDMA- or GSM-modulated cell phone RFR.
[f]Dose-related trend derived from one-tailed linear regression or Jonckheere's test; the trend is significant when P ≤ 0.025.

Table E-4. DNA Damage in Female Mice Exposed to CDMA-modulated Cell Phone RFR for 14 Weeks (100-Cell Method)[a]

	Dose (W/kg)	Percent Tail DNA[b]	P Value[c]	Percent Hedgehogs[b]
Frontal Cortex				
Sham Control[d]	0	8.11 ± 2.13		3.40 ± 1.47
CDMA	2.5	4.88 ± 0.55	0.911	0.80 ± 0.49
	5	4.89 ± 0.57	0.955	1.20 ± 0.49
	10	4.80 ± 0.90	0.968	0.80 ± 0.58
		P = 0.935[e]		
Hippocampus				
Sham Control	0	8.15 ± 1.65		2.60 ± 1.69
CDMA	2.5	5.76 ± 1.00	0.839	1.80 ± 0.80
	5	5.22 ± 1.02	0.903	1.20 ± 0.58
	10	5.34 ± 1.82	0.925	2.20 ± 0.97
		P = 0.892		
Cerebellum				
Sham Control	0	5.88 ± 0.85		0.20 ± 0.20
CDMA	2.5	6.78 ± 1.67	0.296	1.75 ± 1.03
	5	8.39 ± 1.13	0.194	0.20 ± 0.20
	10	6.73 ± 0.77	0.207	0.40 ± 0.40
		P = 0.298		
Liver				
Sham Control	0	5.48 ± 0.60		0.60 ± 0.40
CDMA	2.5	7.54 ± 0.90	0.034	1.00 ± 0.45
	5	7.36 ± 0.72	0.041	4.40 ± 2.11
	10	7.63 ± 0.59	0.030	2.00 ± 0.77
		P = 0.050		
Peripheral Blood				
Sham Control	0	1.03 ± 0.13		0.20 ± 0.20
CDMA	2.5	2.52 ± 0.54	0.020	2.00 ± 1.14
	5	1.71 ± 0.37	0.024	0
	10	2.20 ± 0.19	0.018	0.20 ± 0.20
		P = 0.085		

[a]Study was performed at ILS, Inc. The detailed protocol (100 cell) is presented by Recio et al.[195]. Groups of five mice per exposure group were 5 to 6 weeks old when exposure began.
[b]Mean ± standard error.
[c]Pairwise comparison with the sham control group; exposed group values are significant at P ≤ 0.025 by Williams' test.
[d]No exposure to CDMA-modulated cell phone RFR.
[e]Dose-related trend derived from one-tailed linear regression or Jonckheere's test; the trend is significant when P ≤ 0.025.

Table E-5. Damage in Female Mice Exposed to GSM-modulated Cell Phone RFR for 14 Weeks (100-Cell Method)[a]

	Dose (W/kg)	Percent Tail DNA[b]	P Value[c]	Percent Hedgehogs[b]
Frontal Cortex				
Sham Control[d]	0	8.11 ± 2.13		3.40 ± 1.47
GSM	2.5	7.33 ± 0.90	0.657	1.00 ± 0.45
	5	7.69 ± 1.98	0.744	2.00 ± 0.84
	10	5.74 ± 0.62	0.779	1.00 ± 0.32
		P = 0.861[e]		
Hippocampus				
Sham Control	0	8.15 ± 1.65		2.60 ± 1.69
GSM	2.5	6.23 ± 1.00	0.866	0.80 ± 0.58
	5	4.54 ± 1.29	0.923	1.20 ± 0.58
	10	5.22 ± 1.23	0.942	1.60 ± 1.36
		P = 0.933		
Cerebellum				
Sham Control	0	5.88 ± 0.85		0.20 ± 0.20
GSM	2.5	6.56 ± 1.22	1.000	1.20 ± 0.73
	5	5.26 ± 0.59	1.000	0.60 ± 0.40
	10	6.54 ± 1.71	1.000	1.80 ± 0.73
		P = 0.606		
Liver				
Sham Control	0	5.48 ± 0.60		0.60 ± 0.40
GSM	2.5	7.06 ± 0.61	0.096	3.40 ± 1.17
	5	6.36 ± 0.25	0.117	1.20 ± 0.37
	10	6.47 ± 0.79	0.124	2.60 ± 1.33
		P = 0.249		
Peripheral Blood				
Sham Control	0	1.03 ± 0.13		0.20 ± 0.20
GSM	2.5	1.25 ± 0.44	0.335	0.20 ± 0.20
	5	1.17 ± 0.08	0.400	0
	10	1.32 ± 0.34	0.316	0
		P = 0.266		

[a]Study was performed at ILS, Inc. The detailed protocol (100 cell) is presented by Recio et al.[195]. Groups of five mice per exposure group were 5 to 6 weeks old when exposure began.
[b]Mean ± standard error.
[c]Pairwise comparison with the sham control group; exposed group values are significant at $P \leq 0.025$ by Williams' test.
[d]No exposure to GSM-modulated cell phone RFR.
[e]Dose-related trend derived from one-tailed linear regression or Jonckheere's test; the trend is significant when $P \leq 0.025$.

Table E-6. DNA Damage in Female Mice Exposed to CDMA- or GSM-modulated Cell Phone RFR for 14 Weeks (150-Cell Method)[a]

	Dose (W/kg)	Percent Tail DNA[b]	P Value[c]	Percent Hedgehogs[b,d]
Liver				
Sham Control[e]	0	4.34 ± 0.60		0
CDMA	2.5	6.20 ± 0.99	0.050	0
	5	8.30 ± 0.92	0.009	0
	10	6.14 ± 0.26	0.009	0
		P = 0.100[f]		
GSM	2.5	7.44 ± 0.48	0.027	0
	5	5.45 ± 0.96	0.032	0
	10	6.52 ± 0.75	0.030	0
		P = 0.133		
Peripheral Blood				
Sham Control	0	2.15 ± 0.08		0
CDMA	2.5	3.62 ± 0.66	0.011	0
	5	3.39 ± 0.45	0.015	0.13 ± 0.13
	10	2.45 ± 0.24	0.428	0
		P = 0.173		
GSM	2.5	2.58 ± 0.35	0.504	0
	5	2.23 ± 0.19	1.000	0
	10	2.28 ± 0.51	1.000	0
		P = 0.657		

[a]Study was performed at ILS, Inc. The detailed protocol (150 cell) is presented by OECD[180]. Groups of five mice per exposure group were 5 to 6 weeks old when exposure began.
[b]Mean ± standard error.
[c]Pairwise comparison with the sham control group; exposed group values are significant at P ≤ 0.025 by Williams' test.
[d]Percent hedgehogs = estimated as the number of comets with ≥90% tail DNA/150.
[e]No exposure to CDMA- or GSM-modulated cell phone RFR.
[f]Dose-related trend derived from one-tailed linear regression or Jonckheere's test; the trend is significant when P ≤ 0.025.

Table E-7. Frequency of Micronuclei in Peripheral Blood Erythrocytes of Mice Following Exposure to CDMA- or GSM-modulated Cell Phone RFR for 14 Weeks[a]

	Dose (W/kg)	Number of Mice with Erythrocytes Scored	Micronucleated PCEs/ 1,000 PCEs[b]	P Value[c]	Micronucleated NCEs/ 1,000 NCEs[b]	P Value[c]	PCEs[b] (%)	P Value[c]
Male								
Sham Control[d]	0	5	2.55 ± 0.11		1.50 ± 0.04		1.43 ± 0.04	
CDMA	2.5	5	2.44 ± 0.13	0.611	1.45 ± 0.03	0.748	1.45 ± 0.04	0.765
	5	5	2.77 ± 0.13	0.168	1.46 ± 0.04	0.827	1.48 ± 0.04	0.736
	10	5	2.93 ± 0.18	0.044	1.49 ± 0.02	0.736	1.45 ± 0.04	0.778
			P = 0.013[e]		P = 0.497		P = 0.803	
GSM	2.5	5	2.84 ± 0.14	0.384	1.49 ± 0.04	0.695	1.39 ± 0.04	0.667
	5	5	2.47 ± 0.19	0.455	1.45 ± 0.02	0.781	1.38 ± 0.04	0.787
	10	5	2.53 ± 0.13	0.484	1.50 ± 0.02	0.675	1.45 ± 0.07	0.830
			P = 0.733		P = 0.561		P = 0.809	
Female								
Sham Control	0	5	2.72 ± 0.27		1.18 ± 0.02		1.31 ± 0.11	
CDMA	2.5	5	2.16 ± 0.15	0.846	1.06 ± 0.04	0.956	1.31 ± 0.12	1.000
	5	5	2.32 ± 0.22	0.908	1.09 ± 0.03	0.982	1.43 ± 0.11	0.930
	10	5	2.48 ± 0.20	0.883	1.14 ± 0.02	0.929	1.26 ± 0.09	0.935
			P = 0.629		P = 0.585		P = 0.843	
GSM	2.5	5	2.50 ± 0.40	0.774	1.14 ± 0.05	0.827	1.18 ± 0.08	0.671
	5	5	2.35 ± 0.15	0.850	1.09 ± 0.02	0.893	1.16 ± 0.06	0.791
	10	5	2.16 ± 0.15	0.878	1.12 ± 0.04	0.916	1.43 ± 0.08	0.438
			P = 0.937		P = 0.891		P = 0.245	

[a]Study was performed at ILS, Inc. The detailed protocol is presented by Witt et al.[199]. Mice were 5 to 6 weeks old when exposure began. NCE = normochromatic erythrocyte; PCE = polychromatic erythrocyte.
[b]Mean ± standard error.
[c]Pairwise comparison with the sham control group; exposed group values are significant at P ≤ 0.025 by Williams' test.
[d]No exposure to CDMA- or GSM-modulated cell phone RFR.
[e]Dose-related trend derived from one-tailed linear regression or Jonckheere's test; the trend is significant when P ≤ 0.025.

Appendix F. Hematology Results

Tables

Table F-1. Hematology Data for Mice at the 14-week Interim Evaluation in the Two-year GSM-modulated Cell Phone RFR Study F-2
Table F-2. Hematology Data for Mice at the 14-week Interim Evaluation in the Two-year CDMA-modulated Cell Phone RFR Study F-3

Table F-1. Hematology Data for Mice at the 14-week Interim Evaluation in the Two-year GSM-modulated Cell Phone RFR Study[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
n	10	10	10	10
Male				
Hematocrit (%)	54.8 ± 0.5	54.1 ± 0.9	54.2 ± 0.3	53.5 ± 0.5
Manual hematocrit (%)	50 ± 0	49 ± 1[b]	49 ± 0	49 ± 0
Hemoglobin (g/dL)	16.1 ± 0.1	16.0 ± 0.2	16.0 ± 0.1	15.9 ± 0.2
Erythrocytes (106/µL)	10.87 ± 0.09	10.66 ± 0.15	10.76 ± 0.06	10.61 ± 0.10
Reticulocytes (103/µL)	386.3 ± 8.2	363.6 ± 9.3	358.5 ± 7.5	357.9 ± 7.9
Nucleated erythrocytes (/100 leukocytes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Mean cell volume (fL)	50.4 ± 0.1	50.8 ± 0.2	50.4 ± 0.2	50.4 ± 0.2
Mean cell hemoglobin (pg)	14.8 ± 0.0	15.0 ± 0.1	14.9 ± 0.1	15.0 ± 0.1
Mean cell hemoglobin concentration (g/dL)	29.4 ± 0.1	29.5 ± 0.1	29.5 ± 0.1	29.7 ± 0.1
Platelets (103/µL)	1,115 ± 31	1,065 ± 30	1,111 ± 35	1,116 ± 32
Leukocytes (103/µL)	5.80 ± 0.50	5.11 ± 0.53	5.52 ± 0.43	6.30 ± 0.47
Segmented neutrophils (103/µL)	0.68 ± 0.06	0.58 ± 0.07	0.62 ± 0.04	0.67 ± 0.05
Lymphocytes (103/µL)	4.82 ± 0.41	4.28 ± 0.44	4.63 ± 0.37	5.29 ± 0.40
Monocytes (103/µL)	0.09 ± 0.01	0.09 ± 0.01	0.09 ± 0.01	0.11 ± 0.01
Basophils (103/µL)	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.05 ± 0.01
Eosinophils (103/µL)	0.09 ± 0.01	0.07 ± 0.01	0.08 ± 0.01	0.10 ± 0.01
Large unstained cells (103/µL)	0.07 ± 0.01	0.06 ± 0.01	0.07 ± 0.01	0.07 ± 0.01
Female				
Hematocrit (%)	54.9 ± 2.0	55.7 ± 0.9	55.6 ± 0.5	55.2 ± 0.4
Manual hematocrit (%)	50 ± 2	52 ± 1	52 ± 1	51 ± 0
Hemoglobin (g/dL)	16.4 ± 0.5	16.8 ± 0.3	16.8 ± 0.2	16.5 ± 0.1
Erythrocytes (106/µL)	10.77 ± 0.34	10.88 ± 0.16	10.90 ± 0.11	10.75 ± 0.07
Reticulocytes (103/µL)	346.8 ± 17.4	365.5 ± 20.0	328.6 ± 13.5	378.6 ± 15.5
Nucleated erythrocytes (/100 leukocytes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Mean cell volume (fL)	50.9 ± 0.3	51.2 ± 0.2	51.1 ± 0.2	51.4 ± 0.2
Mean cell hemoglobin (pg)	15.2 ± 0.1	15.4 ± 0.1	15.4 ± 0.1	15.3 ± 0.1
Mean cell hemoglobin concentration (g/dL)	29.9 ± 0.3	30.1 ± 0.1	30.2 ± 0.1	29.8 ± 0.1
Platelets (103/µL)	758 ± 65	714 ± 37	717 ± 52	782 ± 29
Leukocytes (103/µL)	5.15 ± 0.57	5.06 ± 0.60	5.07 ± 0.57	4.88 ± 0.58
Segmented neutrophils (103/µL)	0.60 ± 0.08	0.53 ± 0.07	0.44 ± 0.07	0.58 ± 0.06
Lymphocytes (103/µL)	4.35 ± 0.49	4.30 ± 0.51	4.41 ± 0.49	4.09 ± 0.52
Monocytes (103/µL)	0.07 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.08 ± 0.01
Basophils (103/µL)	0.03 ± 0.01	0.04 ± 0.00	0.04 ± 0.01	0.03 ± 0.00
Eosinophils (103/µL)	0.06 ± 0.01	0.07 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
Large unstained cells (103/µL)	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.00

[a]Data are presented as mean ± standard error. Jonckheere's test for trend and Shirley's and Dunn's tests were performed on unrounded data.
[b]n=9.

Table F-2. Hematology Data for Mice at the 14-week Interim Evaluation in the Two-year CDMA-modulated Cell Phone RFR Study[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
n	10	10	10	10
Male				
Hematocrit (%)	54.8 ± 0.5	54.6 ± 0.6	54.0 ± 0.6	54.5 ± 0.6
Manual hematocrit (%)	50 ± 0	50 ± 1	49 ± 1	50 ± 1
Hemoglobin (g/dL)	16.1 ± 0.1	16.0 ± 0.2	16.0 ± 0.2	16.1 ± 0.2
Erythrocytes (10^6/µL)	10.87 ± 0.09	10.77 ± 0.09	10.68 ± 0.12	10.76 ± 0.11
Reticulocytes (10^3/µL)	386.3 ± 8.2	367.1 ± 9.0	360.3 ± 8.8	374.6 ± 6.3
Nucleated erythrocytes (/100 leukocytes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Mean cell volume (fL)	50.4 ± 0.1	50.7 ± 0.2	50.6 ± 0.1	50.7 ± 0.2
Mean cell hemoglobin (pg)	14.8 ± 0.0	14.9 ± 0.1	14.9 ± 0.1	15.0 ± 0.1
Mean cell hemoglobin concentration (g/dL)	29.4 ± 0.1	29.3 ± 0.1	29.5 ± 0.1	29.6 ± 0.1
Platelets (10^3/µL)	1,115 ± 31	1,087 ± 36	1,128 ± 30	1,104 ± 40
Leukocytes (10^3/µL)	5.80 ± 0.50	5.41 ± 0.35	5.57 ± 0.43	5.45 ± 0.44
Segmented neutrophils (10^3/µL)	0.68 ± 0.06	0.59 ± 0.04	0.62 ± 0.05	0.58 ± 0.05
Lymphocytes (10^3/µL)	4.82 ± 0.41	4.57 ± 0.31	4.67 ± 0.38	4.57 ± 0.36
Monocytes (10^3/µL)	0.09 ± 0.01	0.09 ± 0.01	0.10 ± 0.01	0.09 ± 0.01
Basophils (10^3/µL)	0.04 ± 0.01	0.03 ± 0.01	0.04 ± 0.01	0.05 ± 0.01
Eosinophils (10^3/µL)	0.09 ± 0.01	0.07 ± 0.01	0.09 ± 0.01	0.09 ± 0.02
Large unstained cells (10^3/µL)	0.07 ± 0.01	0.06 ± 0.01	0.07 ± 0.01	0.07 ± 0.01
Female				
Hematocrit (%)	54.9 ± 2.0	55.2 ± 0.8	56.4 ± 0.6	56.1 ± 0.4
Manual hematocrit (%)	50 ± 2	52 ± 1	52 ± 1	52 ± 0
Hemoglobin (g/dL)	16.4 ± 0.5	16.6 ± 0.2	17.0 ± 0.2	16.8 ± 0.2
Erythrocytes (10^6/µL)	10.77 ± 0.34	10.78 ± 0.14	11.10 ± 0.11	10.96 ± 0.06
Reticulocytes (10^3/µL)	346.8 ± 17.4	371.2 ± 14.4	366.7 ± 20.6	374.7 ± 13.8
Nucleated erythrocytes (/100 leukocytes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Mean cell volume (fL)	50.9 ± 0.3	51.2 ± 0.2	50.8 ± 0.2	51.2 ± 0.1
Mean cell hemoglobin (pg)	15.2 ± 0.1	15.4 ± 0.1	15.3 ± 0.1	15.3 ± 0.1
Mean cell hemoglobin concentration (g/dL)	29.9 ± 0.3	30.1 ± 0.1	30.1 ± 0.1	29.9 ± 0.2
Platelets (10^3/µL)	758 ± 65	736 ± 53	668 ± 38	685 ± 41
Leukocytes (10^3/µL)	5.15 ± 0.57	5.24 ± 0.45	4.66 ± 0.55	4.53 ± 0.34
Segmented neutrophils (10^3/µL)	0.60 ± 0.08	0.52 ± 0.04	0.51 ± 0.08	0.42 ± 0.05
Lymphocytes (10^3/µL)	4.35 ± 0.49	4.52 ± 0.40	3.95 ± 0.46	3.92 ± 0.31
Monocytes (10^3/µL)	0.07 ± 0.01	0.07 ± 0.01	0.07 ± 0.01	0.07 ± 0.01
Basophils (10^3/µL)	0.03 ± 0.01	0.04 ± 0.00	0.03 ± 0.01	0.03 ± 0.01
Eosinophils (10^3/µL)	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
Large unstained cells (10^3/µL)	0.04 ± 0.01	0.04 ± 0.00	0.04 ± 0.01	0.04 ± 0.00

[a]Data are presented as mean ± standard error. Jonckheere's test for trend and Shirley's and Dunn's tests were performed on unrounded data.

Appendix G. Organ Weights and Organ-Weight-to-Body-Weight Ratios

Tables

Table G-1. Organ Weights and Organ-Weight-to-Body-Weight Ratios for Mice in the 28-day GSM-modulated Cell Phone RFR Study G-2
Table G-2. Organ Weights and Organ-Weight-to-Body-Weight Ratios for Mice at the 14-week Interim Evaluation in the Two-yearGSM-modulated Cell Phone RFR Study G-4
Table G-3. Organ Weights and Organ-Weight-to-Body-Weight Ratios for Mice in the 28-day CDMA-modulated Cell Phone RFR Study G-6
Table G-4. Organ Weights and Organ-Weight-to-Body-Weight Ratios for Mice at the 14-week Interim Evaluation in the Two-yearCDMA-modulated Cell Phone RFR Study G-8

Table G-1. Organ Weights and Organ-Weight-to-Body-Weight Ratios for Mice in the 28-day GSM-modulated Cell Phone RFR Study[a]

	Sham Control	5 W/kg	10 W/kg	15 W/kg
n	10	10	10	10
Male				
Necropsy body wt.	24.9 ± 0.4	25.2 ± 0.4	24.7 ± 0.3	25.0 ± 0.4
R. Adrenal gland				
Absolute	0.0032 ± 0.0006	0.0025 ± 0.0003	0.0031 ± 0.0006[b]	0.0030 ± 0.0003
Relative	0.13 ± 0.02	0.10 ± 0.01	0.12 ± 0.02[b]	0.12 ± 0.01
Brain				
Absolute	0.47 ± 0.00	0.47 ± 0.00	0.47 ± 0.00	0.47 ± 0.00
Relative	19.06 ± 0.28	18.63 ± 0.24	18.86 ± 0.25	18.78 ± 0.33
Heart				
Absolute	0.14 ± 0.00	0.14 ± 0.00	0.14 ± 0.00	0.14 ± 0.00
Relative	5.59 ± 0.14	5.41 ± 0.14	5.50 ± 0.10	5.57 ± 0.15
R. Kidney				
Absolute	0.22 ± 0.01	0.23 ± 0.00	0.22 ± 0.00	0.22 ± 0.01
Relative	8.80 ± 0.14	9.07 ± 0.14	8.90 ± 0.12	8.64 ± 0.15
Liver				
Absolute	1.29 ± 0.03	1.29 ± 0.03	1.25 ± 0.03	1.23 ± 0.03
Relative	51.86 ± 0.73	51.24 ± 0.80	50.63 ± 0.94	49.16 ± 0.95
Lung				
Absolute	0.20 ± 0.01	0.19 ± 0.01[b]	0.20 ± 0.01	0.19 ± 0.01
Relative	7.87 ± 0.35	7.44 ± 0.41[b]	8.14 ± 0.45	7.45 ± 0.54
R. Testis				
Absolute	0.094 ± 0.005	0.097 ± 0.002	0.093 ± 0.005	0.097 ± 0.002
Relative	3.79 ± 0.21	3.88 ± 0.09	3.75 ± 0.21	3.87 ± 0.06
Thymus				
Absolute	0.045 ± 0.002	0.046 ± 0.001	0.046 ± 0.001	0.047 ± 0.002
Relative	1.81 ± 0.06	1.84 ± 0.04	1.84 ± 0.05	1.89 ± 0.11
Female				
Necropsy body wt.	21.7 ± 0.3	21.9 ± 0.2	21.2 ± 0.2	21.0 ± 0.2*
R. Adrenal gland				
Absolute	0.0037 ± 0.0006	0.0031 ± 0.0006	0.0037 ± 0.0005	0.0036 ± 0.0003
Relative	0.17 ± 0.03	0.14 ± 0.03	0.18 ± 0.02	0.17 ± 0.01

	Sham Control	5 W/kg	10 W/kg	15 W/kg
Brain				
Absolute	0.48 ± 0.00	0.49 ± 0.00	0.47 ± 0.00	0.47 ± 0.00
Relative	22.24 ± 0.32	22.15 ± 0.18	22.21 ± 0.24	22.56 ± 0.27
Heart				
Absolute	0.13 ± 0.00	0.13 ± 0.00	0.12 ± 0.00	0.12 ± 0.00*
Relative	6.00 ± 0.19	5.85 ± 0.11	5.77 ± 0.12	5.62 ± 0.17
R. Kidney				
Absolute	0.17 ± 0.00	0.16 ± 0.00	0.15 ± 0.00	0.16 ± 0.00
Relative	7.65 ± 0.18	7.44 ± 0.13	7.27 ± 0.18	7.39 ± 0.11
Liver				
Absolute	1.14 ± 0.03	1.18 ± 0.02	1.10 ± 0.02	1.07 ± 0.03
Relative	52.61 ± 0.66	53.72 ± 0.85	51.77 ± 0.92	50.72 ± 0.95
Lung				
Absolute	0.18 ± 0.01	0.19 ± 0.01	0.17 ± 0.01	0.17 ± 0.00
Relative	8.48 ± 0.45	8.45 ± 0.34	8.18 ± 0.25	8.06 ± 0.19
Thymus				
Absolute	0.056 ± 0.001	0.057 ± 0.001	0.054 ± 0.001	0.055 ± 0.002
Relative	2.57 ± 0.07	2.59 ± 0.04	2.53 ± 0.07	2.62 ± 0.11

*Significantly different ($P \leq 0.05$) from the sham control group by Williams' or Dunnett's test.
[a]Organ weights (absolute weights) and body weights are given in grams; organ-weight-to-body-weight ratios (relative weights) are given as mg organ weight/g body weight (mean ± standard error).
[b]n=9.

Table G-2. Organ Weights and Organ-Weight-to-Body-Weight Ratios for Mice at the 14-week Interim Evaluation in the Two-yearGSM-modulated Cell Phone RFR Study[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
n	10	10	10	10
Male				
Necropsy body wt.	34.8 ± 0.8	33.3 ± 0.8	34.3 ± 0.6	33.0 ± 0.5
Brain				
Absolute	0.48 ± 0.01	0.48 ± 0.00	0.47 ± 0.00	0.47 ± 0.01
Relative	13.74 ± 0.43	14.44 ± 0.39	13.73 ± 0.28	14.18 ± 0.22
R. Epididymis				
Absolute	0.0504 ± 0.0024	0.0466 ± 0.0023	0.0471 ± 0.0029	0.0489 ± 0.0016
Relative	1.45 ± 0.06	1.40 ± 0.05	1.37 ± 0.07	1.49 ± 0.05
L. Epididymis				
Absolute	0.0478 ± 0.0019	0.0499 ± 0.0026	0.0500 ± 0.0026	0.0468 ± 0.0023
Relative	1.38 ± 0.06	1.50 ± 0.07	1.46 ± 0.07	1.43 ± 0.09
Heart				
Absolute	0.16 ± 0.00[b]	0.17 ± 0.01	0.16 ± 0.00[b]	0.16 ± 0.01
Relative	4.52 ± 0.09[b]	5.06 ± 0.18	4.75 ± 0.13[b]	4.87 ± 0.21
R. Kidney				
Absolute	0.27 ± 0.01	0.26 ± 0.01	0.25 ± 0.00*	0.25 ± 0.01**
Relative	7.80 ± 0.17	7.89 ± 0.18	7.44 ± 0.14	7.63 ± 0.19
L. Kidney				
Absolute	0.26 ± 0.01	0.25 ± 0.01	0.25 ± 0.01	0.23 ± 0.00**
Relative	7.54 ± 0.15	7.65 ± 0.15	7.20 ± 0.16	7.08 ± 0.16
Liver				
Absolute	1.54 ± 0.05	1.44 ± 0.05	1.38 ± 0.03*[b]	1.39 ± 0.03*[b]
Relative	44.27 ± 0.73	43.18 ± 0.85	40.73 ± 0.82*[b]	42.31 ± 1.01[b]
Lung				
Absolute	0.28 ± 0.02	0.29 ± 0.02	0.24 ± 0.01	0.27 ± 0.02
Relative	7.84 ± 0.58	8.62 ± 0.58	6.98 ± 0.34	8.24 ± 0.68
R. Testis				
Absolute	0.110 ± 0.002	0.111 ± 0.004	0.102 ± 0.008	0.109 ± 0.002
Relative	3.16 ± 0.10	3.34 ± 0.11	2.98 ± 0.22	3.31 ± 0.09
L. Testis				
Absolute	0.104 ± 0.002	0.107 ± 0.002	0.101 ± 0.007	0.105 ± 0.002
Relative	3.01 ± 0.12	3.22 ± 0.09	2.96 ± 0.21	3.20 ± 0.09

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Thymus				
Absolute	0.035 ± 0.002	0.037 ± 0.002	0.037 ± 0.002	0.036 ± 0.002
Relative	1.02 ± 0.07	1.10 ± 0.04	1.07 ± 0.05	1.10 ± 0.04
Female				
Necropsy body wt.	24.4 ± 0.4	24.9 ± 0.5	25.0 ± 0.5	26.2 ± 0.7*
Brain				
Absolute	0.49 ± 0.00	0.49 ± 0.00	0.49 ± 0.00	0.49 ± 0.01
Relative	20.21 ± 0.32	19.85 ± 0.37	19.78 ± 0.36	18.86 ± 0.40*
Heart				
Absolute	0.15 ± 0.01	0.16 ± 0.01	0.16 ± 0.01	0.16 ± 0.01
Relative	6.24 ± 0.25	6.34 ± 0.25	6.31 ± 0.22	6.11 ± 0.28
R. Kidney				
Absolute	0.18 ± 0.00	0.18 ± 0.00	0.17 ± 0.00	0.17 ± 0.01
Relative	7.26 ± 0.13	7.08 ± 0.18	6.92 ± 0.23	6.65 ± 0.17*
L. Kidney				
Absolute	0.16 ± 0.00	0.16 ± 0.00	0.15 ± 0.00	0.16 ± 0.01
Relative	6.52 ± 0.16	6.35 ± 0.08	6.19 ± 0.15	6.20 ± 0.16
Liver				
Absolute	1.21 ± 0.03	1.24 ± 0.03	1.22 ± 0.02	1.28 ± 0.05
Relative	49.60 ± 0.66	49.76 ± 0.59	48.96 ± 0.75	48.94 ± 1.28
Lung				
Absolute	0.31 ± 0.02	0.34 ± 0.02	0.32 ± 0.01	0.31 ± 0.01
Relative	12.59 ± 0.60	13.45 ± 0.73	12.75 ± 0.39	11.75 ± 0.60
R. Ovary				
Absolute	0.0077 ± 0.0004	0.0072 ± 0.0006	0.0067 ± 0.0009	0.0070 ± 0.0006
Relative	0.32 ± 0.02	0.29 ± 0.02	0.27 ± 0.04	0.27 ± 0.02
L. Ovary				
Absolute	0.0069 ± 0.0009	0.0058 ± 0.0006	0.0053 ± 0.0008	0.0064 ± 0.0003
Relative	0.28 ± 0.04	0.23 ± 0.02	0.21 ± 0.03	0.25 ± 0.01
Thymus				
Absolute	0.041 ± 0.003	0.044 ± 0.001	0.043 ± 0.002	0.049 ± 0.002*
Relative	1.66 ± 0.10	1.75 ± 0.04	1.73 ± 0.04	1.86 ± 0.06

*Significantly different ($P \leq 0.05$) from the sham control group by Williams' or Dunnett's test.
**$P \leq 0.01$.
[a]Organ weights (absolute weights) and body weights are given in grams; organ-weight-to-body-weight ratios (relative weights) are given as mg organ weight/g body weight (mean ± standard error).
[b]n=9.

Table G-3. Organ Weights and Organ-Weight-to-Body-Weight Ratios for Mice in the 28-day CDMA-modulated Cell Phone RFR Study[a]

	Sham Control	5 W/kg	10 W/kg	15 W/kg
n	10	10	10	10
Male				
Necropsy body wt.	24.9 ± 0.4	24.3 ± 0.3	25.2 ± 0.4	25.1 ± 0.3
R. Adrenal gland				
Absolute	0.0032 ± 0.0006	0.0025 ± 0.0002	0.0026 ± 0.0006	0.0030 ± 0.0006[b]
Relative	0.13 ± 0.02	0.10 ± 0.01	0.10 ± 0.02	0.12 ± 0.02[b]
Brain				
Absolute	0.47 ± 0.00	0.46 ± 0.00	0.48 ± 0.00	0.47 ± 0.00
Relative	19.06 ± 0.28	19.14 ± 0.13	19.11 ± 0.25	18.52 ± 0.24
Heart				
Absolute	0.14 ± 0.00	0.13 ± 0.00	0.14 ± 0.00	0.14 ± 0.00
Relative	5.59 ± 0.14	5.52 ± 0.12	5.40 ± 0.12	5.58 ± 0.14
R. Kidney				
Absolute	0.22 ± 0.01	0.21 ± 0.01	0.22 ± 0.01	0.22 ± 0.01
Relative	8.80 ± 0.14	8.77 ± 0.16	8.86 ± 0.20	8.67 ± 0.20
Liver				
Absolute	1.29 ± 0.03	1.24 ± 0.02	1.29 ± 0.02	1.25 ± 0.02
Relative	51.86 ± 0.73	51.26 ± 0.73	51.20 ± 0.82	49.85 ± 0.77
Lung				
Absolute	0.20 ± 0.01	0.18 ± 0.00	0.19 ± 0.01	0.18 ± 0.00
Relative	7.87 ± 0.35	7.55 ± 0.16	7.45 ± 0.24	7.13 ± 0.16
R. Testis				
Absolute	0.094 ± 0.005	0.094 ± 0.003	0.099 ± 0.001	0.096 ± 0.003
Relative	3.79 ± 0.21	3.88 ± 0.13	3.94 ± 0.09	3.81 ± 0.11
Thymus				
Absolute	0.045 ± 0.002	0.045 ± 0.001	0.046 ± 0.002	0.043 ± 0.001
Relative	1.81 ± 0.06	1.86 ± 0.04	1.85 ± 0.10	1.71 ± 0.04
Female				
Necropsy body wt.	21.7 ± 0.3	21.7 ± 0.3	21.6 ± 0.3	21.2 ± 0.3
R. Adrenal gland				
Absolute	0.0037 ± 0.0006	0.0044 ± 0.0005	0.0037 ± 0.0005	0.0037 ± 0.0005
Relative	0.17 ± 0.03	0.20 ± 0.02	0.17 ± 0.03	0.17 ± 0.02
Brain				
Absolute	0.48 ± 0.00	0.48 ± 0.00	0.48 ± 0.00	0.48 ± 0.00

	Sham Control	5 W/kg	10 W/kg	15 W/kg
Relative	22.24 ± 0.32	22.26 ± 0.37	22.29 ± 0.29	22.48 ± 0.29
Heart				
Absolute	0.13 ± 0.00	0.12 ± 0.00	0.13 ± 0.00	0.12 ± 0.00
Relative	6.00 ± 0.19	5.73 ± 0.17	5.89 ± 0.16	5.81 ± 0.13
R. Kidney				
Absolute	0.17 ± 0.00	0.16 ± 0.00	0.16 ± 0.00	0.15 ± 0.00*
Relative	7.65 ± 0.18	7.21 ± 0.14	7.39 ± 0.23	7.24 ± 0.13
Liver				
Absolute	1.14 ± 0.03	1.14 ± 0.02	1.13 ± 0.02	1.09 ± 0.02
Relative	52.61 ± 0.66	52.79 ± 0.74	52.63 ± 0.68	51.27 ± 0.66
Lung				
Absolute	0.18 ± 0.01	0.20 ± 0.01	0.19 ± 0.01	0.17 ± 0.00
Relative	8.48 ± 0.45	9.14 ± 0.34	8.78 ± 0.40	8.18 ± 0.22
Thymus				
Absolute	0.056 ± 0.001	0.055 ± 0.002	0.054 ± 0.002	0.052 ± 0.002
Relative	2.57 ± 0.07	2.53 ± 0.08	2.52 ± 0.08	2.47 ± 0.08

*Significantly different ($P \leq 0.05$) from the sham control group by Williams' or Dunnett's test
[a]Organ weights (absolute weights) and body weights are given in grams; organ-weight-to-body-weight ratios (relative weights) are given as mg organ weight/g body weight (mean ± standard error).
[b]n=9.

Table G-4. Organ Weights and Organ-Weight-to-Body-Weight Ratios for Mice at the 14-week Interim Evaluation in the Two-yearCDMA-modulated Cell Phone RFR Study[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
n	10	10	10	10
Male				
Necropsy body wt.	34.8 ± 0.8	35.5 ± 0.4	33.2 ± 0.7	36.2 ± 0.7
Brain				
Absolute	0.48 ± 0.01	0.48 ± 0.01	0.47 ± 0.00	0.47 ± 0.00
Relative	13.74 ± 0.43	13.46 ± 0.21	14.15 ± 0.30	13.09 ± 0.26
R. Epididymis				
Absolute	0.0504 ± 0.0024	0.0499 ± 0.0020[b]	0.0472 ± 0.0021[b]	0.0521 ± 0.0036
Relative	1.45 ± 0.06	1.41 ± 0.07[b]	1.43 ± 0.08[b]	1.44 ± 0.10
L. Epididymis				
Absolute	0.0478 ± 0.0019	0.0510 ± 0.0020	0.0467 ± 0.0011	0.0508 ± 0.0033
Relative	1.38 ± 0.06	1.44 ± 0.05	1.41 ± 0.03	1.40 ± 0.09
Heart				
Absolute	0.16 ± 0.00[b]	0.16 ± 0.00[b]	0.16 ± 0.00	0.16 ± 0.01
Relative	4.52 ± 0.09[b]	4.65 ± 0.11[b]	4.70 ± 0.10	4.35 ± 0.09
R. Kidney				
Absolute	0.27 ± 0.01	0.28 ± 0.00	0.25 ± 0.01*	0.25 ± 0.01
Relative	7.80 ± 0.17	7.99 ± 0.16	7.54 ± 0.17	6.99 ± 0.17**
L. Kidney				
Absolute	0.26 ± 0.01	0.27 ± 0.01[b]	0.24 ± 0.00**	0.24 ± 0.00**
Relative	7.54 ± 0.15	7.57 ± 0.23[b]	7.10 ± 0.17	6.57 ± 0.12**
Liver				
Absolute	1.54 ± 0.05	1.58 ± 0.06	1.39 ± 0.04*	1.49 ± 0.04
Relative	44.27 ± 0.73	44.37 ± 1.38	41.76 ± 0.70	41.25 ± 0.85*
Lung				
Absolute	0.28 ± 0.02	0.28 ± 0.02	0.27 ± 0.02	0.31 ± 0.03
Relative	7.84 ± 0.58	7.84 ± 0.55	8.13 ± 0.46	8.62 ± 0.80
R. Testis				
Absolute	0.110 ± 0.002	0.109 ± 0.005	0.110 ± 0.003	0.110 ± 0.003
Relative	3.16 ± 0.10	3.09 ± 0.14	3.31 ± 0.10	3.04 ± 0.09
L. Testis				
Absolute	0.104 ± 0.002	0.106 ± 0.005	0.105 ± 0.001	0.109 ± 0.002
Relative	3.01 ± 0.12	2.99 ± 0.14	3.18 ± 0.07	3.01 ± 0.07
Thymus				

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Absolute	0.035 ± 0.002	0.035 ± 0.002	0.033 ± 0.001	0.043 ± 0.002*
Relative	1.02 ± 0.07	1.00 ± 0.06	1.00 ± 0.03	1.18 ± 0.05
Female				
Necropsy body wt.	24.4 ± 0.4	25.5 ± 0.5	25.7 ± 0.7	24.5 ± 0.3
Brain				
Absolute	0.49 ± 0.00	0.50 ± 0.01	0.49 ± 0.01	0.49 ± 0.00
Relative	20.21 ± 0.32	19.64 ± 0.50	19.28 ± 0.42	20.04 ± 0.27
Heart				
Absolute	0.15 ± 0.01	0.17 ± 0.01	0.16 ± 0.01	0.15 ± 0.00
Relative	6.24 ± 0.25	6.50 ± 0.15	6.30 ± 0.28	6.11 ± 0.16
R. Kidney				
Absolute	0.18 ± 0.00	0.18 ± 0.01	0.18 ± 0.00	0.16 ± 0.00
Relative	7.26 ± 0.13	7.16 ± 0.17	7.13 ± 0.22	6.68 ± 0.17
L. Kidney				
Absolute	0.16 ± 0.00	0.17 ± 0.00	0.17 ± 0.00	0.15 ± 0.00
Relative	6.52 ± 0.16	6.54 ± 0.11	6.47 ± 0.20	6.20 ± 0.16
Liver				
Absolute	1.21 ± 0.03	1.26 ± 0.03	1.25 ± 0.02	1.17 ± 0.04
Relative	49.60 ± 0.66	49.38 ± 0.72	48.97 ± 0.89	47.65 ± 1.15
Lung				
Absolute	0.31 ± 0.02	0.33 ± 0.02	0.33 ± 0.01	0.31 ± 0.01
Relative	12.59 ± 0.60	13.03 ± 0.48	12.87 ± 0.40	12.67 ± 0.52
R. Ovary				
Absolute	0.0077 ± 0.0004	0.0080 ± 0.0007	0.0071 ± 0.0007	0.0068 ± 0.0005
Relative	0.32 ± 0.02	0.32 ± 0.03	0.28 ± 0.03	0.28 ± 0.02
L. Ovary				
Absolute	0.0069 ± 0.0009	0.0068 ± 0.0005	0.0060 ± 0.0006	0.0055 ± 0.0005
Relative	0.28 ± 0.04	0.27 ± 0.02	0.23 ± 0.03	0.22 ± 0.02
Thymus				
Absolute	0.041 ± 0.003	0.043 ± 0.002	0.044 ± 0.002	0.045 ± 0.001
Relative	1.66 ± 0.10	1.70 ± 0.04	1.71 ± 0.05	1.83 ± 0.05

*Significantly different ($P \leq 0.05$) from the sham control group by Williams' or Dunnett's test.
**$P \leq 0.01$.
[a]Organ weights (absolute weights) and body weights are given in grams; organ-weight-to-body-weight ratios (relative weights) are given as mg organ weight/g body weight (mean ± standard error).
[b]n=9.

Appendix H. Reproductive Tissue Evaluations and Estrous Cycle Characterization

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Table H-1. Summary of Reproductive Tissue Evaluations for Male Mice at the 14-week Interim Evaluation in the Two-yearGSM-modulated Cell Phone RFR Study[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
n	10	10	10	10
Weights (g)				
Necropsy body wt	34.8 ± 0.8	33.3 ± 0.8	34.3 ± 0.6	33.0 ± 0.5
L. Cauda epididymis	0.020 ± 0.001	0.020 ± 0.001	0.021 ± 0.001	0.019 ± 0.001
L. Epididymis	0.048 ± 0.002	0.050 ± 0.003	0.050 ± 0.003	0.047 ± 0.002
L. Testis	0.104 ± 0.002	0.107 ± 0.002	0.101 ± 0.007	0.105 ± 0.002
Spermatid measurements				
Spermatid heads (10^6/testis)	21.9 ± 1.9	22.2 ± 1.6	20.2 ± 3.0	22.4 ± 1.4
Spermatid heads (10^3/mg testis)	210.6 ± 17.0	208.2 ± 13.9	186.4 ± 26.6	213.0 ± 12.2
Epididymal spermatozoal measurements				
Sperm motility (%)	73.5 ± 5.7	66.8 ± 6.1	66.2 ± 7.9	76.8 ± 5.0
Sperm (10^6/cauda epididymis)	24.2 ± 4.7	18.0 ± 3.2	18.3 ± 2.2	15.9 ± 2.5
Sperm (10^3/mg cauda epididymis)	1,254.1 ± 258.5	921.1 ± 164.5	880.0 ± 122.2	825.1 ± 129.7

[a]Data are presented as mean ± standard error. Differences from the sham control group are not significant by Williams' or Dunnett's test (body and tissue weights) or Dunn's test (spermatid and epididymal spermatozoal measurements).

Table H-2. Estrous Cycle Characterization for Female Mice at the 14-week Interim Evaluation in the Two-yearGSM-modulated Cell Phone RFR Study[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Number weighed at necropsy	10	10	10	10
Necropsy body wt (g)	24.4 ± 0.4	24.9 ± 0.5	25.0 ± 0.5	26.2 ± 0.7*
Proportion of regular cycling females[b]	10/10	10/10	10/10	10/10
Estrous cycle length (days)	4.0 ± 0.05	4.0 ± 0.03	4.2 ± 0.22	4.2 ± 0.21
Estrous stages (% of cycle)				
Diestrus	33.8	32.5	33.8	42.0
Proestrus	0.6	1.3	0.0	0.0
Estrus	51.0	49.0	49.7	47.8
Metestrus	14.6	15.9	15.9	9.6
Uncertain diagnoses	0.0	1.3	0.6	0.6

*Significantly different ($P \leq 0.05$) from the sham control group by Williams' or Dunnett's test.
[a]Necropsy body weights and estrous cycle length data are presented as mean ± standard error. Differences from the sham control group are not significant by Dunn's test (estrous cycle length). Tests for equality of transition probability matrices among all groups and between the sham control group and each exposed group indicated exposed females did not have extended estrus or diestrus.
[b]Number of females with a regular cycle/number of females cycling.

Table H-3. Results of Vaginal Cytology Study Using the Transition Matrix Approach in Female Mice at the 14-week Interim Evaluation in the Two-yearGSM-modulated Cell Phone RFR Study

Stage	Comparison	P Value	Trend[a]
Overall Tests	Overall	0.649	
Overall Tests	2.5 W/kg vs. Sham Controls	0.999	
Overall Tests	5 W/kg vs. Sham Controls	0.42	
Overall Tests	10 W/kg vs. Sham Controls	0.291	
Extended Estrus	Overall	0.997	
Extended Estrus	2.5 W/kg vs. Sham Controls	0.999	
Extended Estrus	5 W/kg vs. Sham Controls	0.755	
Extended Estrus	10 W/kg vs. Sham Controls	1	
Extended Diestrus	Overall	0.414	
Extended Diestrus	2.5 W/kg vs. Sham Controls	1	
Extended Diestrus	5 W/kg vs. Sham Controls	0.324	
Extended Diestrus	10 W/kg vs. Sham Controls	0.147	
Extended Metestrus	Overall	1	
Extended Metestrus	2.5 W/kg vs. Sham Controls	1	
Extended Metestrus	5 W/kg vs. Sham Controls	1	
Extended Metestrus	10 W/kg vs. Sham Controls	1	
Extended Proestrus	Overall	1	
Extended Proestrus	2.5 W/kg vs. Sham Controls	1	
Extended Proestrus	5 W/kg vs. Sham Controls	1	
Extended Proestrus	10 W/kg vs. Sham Controls	1	
Skipped Estrus	Overall	1	
Skipped Estrus	2.5 W/kg vs. Sham Controls	1	
Skipped Estrus	5 W/kg vs. Sham Controls	1	
Skipped Estrus	10 W/kg vs. Sham Controls	1	
Skipped Diestrus	Overall	1	
Skipped Diestrus	2.5 W/kg vs. Sham Controls	1	
Skipped Diestrus	5 W/kg vs. Sham Controls	1	
Skipped Diestrus	10 W/kg vs. Sham Controls	1	

[a]N means that the treated group had a lower probability of transitioning to the relevant abnormal state (extended estrus, extended diestrus, extended metestrus, extended proestrus, skipped estrus, or skipped diestrus) than did the sham control group.

Table H-4. Summary of Reproductive Tissue Evaluations for Male Mice at the 14-week Interim Evaluation in the Two-yearCDMA-modulated Cell Phone RFR Study[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
n	10	10	10	10
Weights (g)				
Necropsy body wt	34.8 ± 0.8	35.5 ± 0.4	33.2 ± 0.7	36.2 ± 0.7
L. Cauda epididymis	0.020 ± 0.001	0.021 ± 0.001	0.020 ± 0.000	0.021 ± 0.000
L. Epididymis	0.048 ± 0.002	0.051 ± 0.002	0.047 ± 0.001	0.051 ± 0.003
L. Testis	0.104 ± 0.002	0.106 ± 0.005	0.105 ± 0.001	0.109 ± 0.002
Spermatid measurements				
Spermatid heads (10^6/testis)	21.9 ± 1.9	21.2 ± 1.9	23.4 ± 1.6	22.5 ± 1.8
Spermatid heads (10^3/mg testis)	210.6 ± 17.0	196.6 ± 11.1	222.8 ± 15.0	205.4 ± 14.6
Epididymal spermatozoal measurements				
Sperm motility (%)	73.5 ± 5.7	66.3 ± 6.7	67.5 ± 5.9	68.1 ± 8.3
Sperm (10^6/cauda epididymis)	24.2 ± 4.7	18.5 ± 4.8	13.0 ± 2.1	18.4 ± 1.5
Sperm (10^3/mg cauda epididymis)	1,254.1 ± 258.5	851.4 ± 181.3	674.6 ± 118.8	892.2 ± 69.2

[a]Data are presented as mean ± standard error. Differences from the sham control group are not significant by Williams' or Dunnett's test (body and tissue weights) or Dunn's test (spermatid and epididymal spermatozoal measurements).

Table H-5. Estrous Cycle Characterization for Female Mice at the 14-week Interim Evaluation in the Two-yearCDMA-modulated Cell Phone RFR Study[a]

	Sham Control	2.5 W/kg	5 W/kg	10 W/kg
Number weighed at necropsy	10	10	10	10
Necropsy body wt (g)	24.4 ± 0.4	25.5 ± 0.5	25.7 ± 0.7	24.5 ± 0.3
Proportion of regular cycling females[b]	10/10	10/10	10/10	10/10
Estrous cycle length (days)	4.0 ± 0.05	4.8 ± 0.71	4.0 ± 0.07	4.0 ± 0.00
Estrous stages (% of cycle)				
Diestrus	33.8	34.8	42.0	29.9
Proestrus	0.6	1.3	0.6	1.9
Estrus	51.0	47.5	47.8	49.0
Metestrus	14.6	15.2	8.9	19.1
Uncertain diagnoses	0.0	1.3	0.6	0.0

[a]Necropsy body weights and estrous cycle length data are presented as mean ± standard error. Differences from the sham control group are not significant by Jonckheere's, Williams', or Dunnett's test (body weight) or Jonckheere's, Shirley's, or Dunn's test (estrous cycle length). Tests for equality of transition probability matrices among all groups and between the sham control group and each exposed group indicated exposed females did not have extended estrus or diestrus.
[b]Number of females with a regular cycle/number of females cycling.

Table H-6. Results of Vaginal Cytology Study Using the Transition Matrix Approach in Female Mice at the 14-week Interim Evaluation in the Two-yearCDMA-modulated Cell Phone RFR Study

Stage	Comparison	P Value	Trend[a]
Overall Tests	Overall	<0.001	
Overall Tests	2.5 W/kg vs. Sham Controls	<0.001	
Overall Tests	5 W/kg vs. Sham Controls	0.003	
Overall Tests	10 W/kg vs. Sham Controls	0.209	N
Extended Estrus	Overall	0.042	
Extended Estrus	2.5 W/kg vs. Sham Controls	0.012	
Extended Estrus	5 W/kg vs. Sham Controls	0.333	
Extended Estrus	10 W/kg vs. Sham Controls	0.358	N
Extended Diestrus	Overall	0.006	
Extended Diestrus	2.5 W/kg vs. Sham Controls	0.113	
Extended Diestrus	5 W/kg vs. Sham Controls	0.002	
Extended Diestrus	10 W/kg vs. Sham Controls	0.602	N
Extended Metestrus	Overall	1	
Extended Metestrus	2.5 W/kg vs. Sham Controls	1	
Extended Metestrus	5 W/kg vs. Sham Controls	1	
Extended Metestrus	10 W/kg vs. Sham Controls	1	
Extended Proestrus	Overall	1	
Extended Proestrus	2.5 W/kg vs. Sham Controls	1	
Extended Proestrus	5 W/kg vs. Sham Controls	1	
Extended Proestrus	10 W/kg vs. Sham Controls	1	
Skipped Estrus	Overall	1	
Skipped Estrus	2.5 W/kg vs. Sham Controls	1	
Skipped Estrus	5 W/kg vs. Sham Controls	1	
Skipped Estrus	10 W/kg vs. Sham Controls	1	
Skipped Diestrus	Overall	1	
Skipped Diestrus	2.5 W/kg vs. Sham Controls	0.934	
Skipped Diestrus	5 W/kg vs. Sham Controls	1	
Skipped Diestrus	10 W/kg vs. Sham Controls	1	
Summary of Significant Groups			
Overall Tests	2.5 W/kg vs. Sham Controls	<0.001	
Overall Tests	5 W/kg vs. Sham Controls	0.003	
Extended Estrus	2.5 W/kg vs. Sham Controls	0.012	
Extended Diestrus	5 W/kg vs. Sham Controls	0.002	

[a]N means that the treated group had a lower probability of transitioning to the relevant abnormal state (extended estrus, extended diestrus, extended metestrus, extended proestrus, skipped estrus, or skipped diestrus) than did the sham control group.

Dose (W/kg)																							
0								E	E	D	E	E	D	D	E	E	D	D	E	E	M	D	E
0								E	M	D	E	D	D	D	E	E	M	D	E	E	D	D	
0								E	M	D	E	E	D	E	E	E	D	D	E	E	E	D	E
0								E	M	D	E	E	D	D	E	E	D	D	E	E	M	D	E
0							E	E	M	D	E	E	M	D	E	E	M	D	E	E	M	D	
0							E	E	M	D	E	E	M	D	E	E	M	D	E	E	M		
0							E	E	M	D	E	E	D	D	E	E	M	D	E	E	M	D	
0							E	E	M	D	E	E	D	D	E	E	M	D	E	E	M		
0							E	D	D	P	E	D	D	E	E	D	D	E	E	M	D	E	
0						D	E	E	D	D	E	E	D	D	E	E	M	D	E	E	M		
2.5								E	E	I	E	E	M	D	E	E	M	D	E	E	D	D	E
2.5								E	M	D	E	E	M	D	E	E	D	D	E	E	M	D	
2.5								E	M	D	E	E	D	E	E	E	D	D	D	E	M	D	E
2.5							E	E	M	D	E	E	M	D	E	E	M	D	E	E	M	D	
2.5							E	M	D	P	E	M	D	E	E	M	D	E	E	M	D		
2.5						E	E	M	D	P	E	D	D	E	E	M	D	E	M	D			
2.5						D	E	E	M	D	E	E	E	D	E	E	D	D	E	E	M		
2.5					M	D	E	E	M	D	E	E	D	D	E	E	M	I	E	E			
2.5					M	D	E	E	M	D	E	E	D	D	E	E	D	D	E	E			
2.5					D	D	E	E	D	D	E	E	D	D	E	E	D	D	E	E			
5								E	E	D	E	M	D	E	E	M	D	E	E	M	D	E	E
5								E	M	D	E	E	M	D	E	E	M	D	E	E	M	D	
5								E	D	D	E	E	M	D	E	E	M	D	E	E	M	D	E
5							E	E	D	D	E	E	D	D	E	E	M	D	E	E	D	D	
5							E	I	D	D	E	E	D	D	E	E	M	D	E	E	D		
5						E	E	E	M	D	E	E	M	D	E	E	E	M	D	E	E		
5						D	E	E	M	D	E	E	M	D	E	E	M	D	E	E	M		
5						D	E	E	D	D	E	E	D	D	E	E	M	D	E	E	M		
5					D	D	E	E	D	D	E	E	M	D	E	E	M	D	E				
5	D	E	E	M	D	D	D	D	D	D	E	D	E	E	E	M							
10								E	E	D	E	E	M	D	E	E	D	D	E	E	D	D	E
10								E	M	D	E	E	M	D	E	E	M	D	E	E	M	D	
10								E	M	D	E	E	D	D	E	E	D	D	E	E	M	D	
10								E	I	D	E	E	D	D	E	E	D	D	E	E	D	D	E
10						D	E	E	D	D	E	E	D	D	E	E	M	D	E	E	M		
10					M	D	E	E	D	D	E	E	M	D	E	E	M	D	E				
10					D	D	E	E	D	D	E	E	D	D	E	E	E	D	E	E			
10				D	D	E	E	E	D	D	E	E	D	D	E	E	D	D	E				
10				D	D	D	E	E	D	D	E	E	M	D	E	E	M	D	E				
10		E	E	D	D	D	D	D	D	D	E	M	D	E	E	D	D						

Figure H-1. Vaginal Cytology Plots for Female Mice at the 14-week Interim Evaluation in the Two-year GSM-modulated Cell Phone RFR Study

I = Insufficient number of cells to determine stage; D = diestrus, P = proestrus, E = estrus, M = metestrusTable H3.

Dose (W/kg)																									
0											E	E	D	E	E	D	D	E	E	D	D	E	E	M	D	E
0											E	M	D	E	D	D	D	E	E	M	D	E	E	D	D	
0											E	M	D	E	E	D	E	E	E	D	D	E	E	E	D	E
0											E	M	D	E	E	D	D	E	E	D	D	E	E	M	D	E
0										E	E	M	D	E	E	M	D	E	E	M	D	E	E	M	D	
0										E	E	M	D	E	E	M	D	E	E	M	D	E	E	M		
0										E	E	M	D	E	E	D	D	E	E	M	D	E	E	M	D	
0										E	E	M	D	E	E	D	D	E	E	M	D	E	E	M		
0										E	D	D	P	E	D	D	E	E	D	D	E	E	M	D	E	
0									D	E	E	D	D	E	E	D	D	E	E	M	D	E	E	M		
2.5											E	M	D	E	E	E	M	D	E	E	E	M	D	E	E	E
2.5											E	D	D	E	E	M	D	E	E	M	D	E	E	M	D	E
2.5											E	D	D	E	E	D	D	E	E	M	D	E	M	E	D	E
2.5										E	E	M	D	E	E	I	D	E	E	D	D	E	E	M	D	
2.5										E	E	D	D	E	E	M	D	E	E	D	D	E	E	M	D	
2.5										E	M	D	P	E	D	E	E	D	D	D	E	E	D	D	E	
2.5									D	E	E	M	D	E	E	E	D	E	E	M	D	E	E	M		
2.5								M	D	E	E	D	D	E	E	M	D	E	E	M	D	E				
2.5								D	D	E	E	M	D	E	E	E	M	D	E	E	E	M				
2.5	D	P	E	M	D	D	D	D	D	D	D	I	D	E	M	D										
5											E	M	D	E	E	D	D	E	E	D	D	E	E	D	D	D
5											E	D	D	E	E	D	D	E	E	D	D	E	E	D	D	E
5											E	D	D	E	E	E	D	D	E	E	D	D	D	D	I	E
5									E	E	E	M	D	E	E	E	D	E	E	D	D	E	E	M		
5									E	E	E	D	D	E	E	M	D	E	E	M	D	E	E			
5									E	E	D	D	P	E	D	D	E	E	D	D	E	E	M	D		
5									D	E	E	M	D	E	E	D	D	E	E	M	D	E	E			
5									D	E	E	M	D	E	E	D	D	E	E	M	D	D	D	D		
5								D	D	E	E	M	D	E	E	M	D	E	E	D	D	E	E			
5					D	D	D	D	D	E	E	D	D	E	M	D	E	E	M							
10											E	M	D	E	E	M	D	E	E	M	D	E	E	M	D	E
10										E	E	M	D	E	E	M	D	E	E	M	D	E	E	M	D	
10										E	E	D	D	E	E	M	D	E	E	M	D	E	E	M		
10										E	E	D	D	E	E	D	D	E	E	M	D	E	E	M		
10										E	D	D	P	E	M	D	E	E	M	D	E	E	M	D	E	
10									D	E	E	M	D	E	E	M	D	E	E	M	D	E	E	M		
10								M	D	E	E	M	D	E	E	M	D	E	E	D	D	E	E			
10								M	D	E	E	D	D	E	E	M	D	E	E	M	D	E	E			
10								M	D	E	E	D	D	E	E	D	D	E	E	M	D	E	E			
10								D	P	E	M	D	P	E	D	D	E	E	M	D	E	E				

Figure H-2. Vaginal Cytology Plots for Female Mice at the 14-week Interim Evaluation in the Two-year CDMA-modulated Cell Phone RFR Study

I = Insufficient number of cells to determine stage; D = diestrus, P = proestrus, E = estrus, M = metestrus.

Appendix I. GSM- and CDMA-modulated Cell Phone RFR Exposure Data

Tables

Table I-1. Summary of GSM-modulated Cell Phone RFR Exposure Data—SAR I-3
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Exposure data include SAR (W/kg) (Table I-1, Table I-5), chamber field strength (V/m) (Tables I2 and I6), and E- and H-field measurements (V/m) (Table I-3, Table I-4, Table I-7, Table I-8). For the medium and high dose GSM chambers, where a second E-field probe was used, the H-field measurements were converted from E-field measurements (E-field divided by 377). Fields were measured continuously throughout the study and measurements were automatically recorded approximately every 20 seconds. For every 20-second interval, the SAR was calculated based on the average H- and/or E-field data. The data presented for each exposure parameter include the mean and standard deviation [expressed in decibels (dB), W/kg, or V/m]; the total number of measurements recorded during the identified period of exposure (>44,000 calculated SAR per month and more than 1.1 million over the course of the 2-year study); the lowest (min) and highest (max) measurement recorded during the given exposure period; the number of measurements that were within the acceptable range; and the ratio of all measurements within range. The data reported for SAR also include the range of animal body weights (g) over the indicated time period of exposure, as well as the selected target SAR for each group. The data reported for field strengths (chamber, E-field, and H-field) include the target range of the field required to maintain appropriate SAR exposures. The minimum and maximum exposure values reported represent a single recorded measurement over the 2-year exposure period. The SAR and chamber-field in the sham and exposure chambers were within the target ranges (defined as ± 2 dB) for >99.85% of recorded measurements over the course of the 2-year study; ≥99.70% of E-field and H-field exposures in the sham and exposure chambers were within the target ranges for all but one chamber (97.35% within range).

The dB is a mathematical transformation of a number or numerical ratio using base 10 logarithms. Multiplication of ratios is transformed into addition of dBs; raising a number to a power is transformed into multiplication of dBs.

In general, dB(power) = 10 × log(R), and dB(field) = 20 × log(R). The formulas differ by a factor of two because power or SAR varies as the square of the fields. For SAR (in watts/kg), the decibel formula is calculated as:

$SAR(dB) = 10 \times \log(SAR_M/SAR_T)$

where SAR_M is the measured value and SAR_T is the target value, and

$-2\ dB = 10 \times \log(SAR_L/SAR_T)$, where SAR_L (low) = $SAR_T \times 10^{-0.2}$

$+2\ dB = 10 \times \log(SAR_H/SAR_T)$, where SAR_H (high) = $SAR_T \times 10^{0.2}$

On this basis, the ± 2 dB range specified by NTP translates to the following ranges for each SAR used in the 2-year study:

Target SAR (W/kg): Acceptable SAR Range (W/kg; ± 2 dB)
2.5: 1.58 to 3.96

5: 3.15 to 7.92

10: 6.31 to 15.85

Table I-1. Summary of GSM-modulated Cell Phone RFR Exposure Data—SAR[a]

Chamber	Weight Range [g]	Target [W/kg]	Mean [W/kg]	Stdev [dB]/[W/kg]	Min [W/kg]	Max [W/kg]	In Range/ Total	Ratio
June 18 to 30, 2012								
Ch11 Mouse GSM High	18.9 to 20.2	10.00	10.08	0.23/0.05	3.944	23.576	19472/19475	1.000
Ch12 Mouse GSM Med	18.9 to 20.2	5.00	5.04	0.21/0.05	2.105	11.918	19472/19475	1.000
Ch14 Mouse GSM Low	18.8 to 20.2	2.50	2.51	0.20/0.05	1.948	3.175	19475/19475	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	19475/19475	1.000
July 1 to 31, 2012								
Ch11 Mouse GSM High	20.2 to 24.1	10.00	10.01	0.23/0.05	7.430	13.279	48731/48731	1.000
Ch12 Mouse GSM Med	20.2 to 24.6	5.00	5.01	0.21/0.05	3.349	7.170	48731/48731	1.000
Ch14 Mouse GSM Low	20.2 to 24.5	2.50	2.50	0.18/0.04	2.103	3.135	48731/48731	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48731/48731	1.000
August 1 to 31, 2012								
Ch11 Mouse GSM High	24.1 to 27.5	10.00	10.02	0.20/0.05	6.893	13.910	47488/47488	1.000
Ch12 Mouse GSM Med	24.6 to 27.9	5.00	5.03	0.20/0.05	3.911	6.803	47488/47488	1.000
Ch14 Mouse GSM Low	24.5 to 27.2	2.50	2.50	0.18/0.04	1.900	3.441	47488/47488	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47488/47488	1.000
September 1 to 30, 2012								
Ch11 Mouse GSM High	27.5 to 29.3	10.00	10.01	0.21/0.05	5.187	12.693	47186/47187	1.000
Ch12 Mouse GSM Med	27.9 to 30.0	5.00	5.01	0.19/0.04	2.558	6.280	47184/47185	1.000
Ch14 Mouse GSM Low	27.2 to 29.2	2.50	2.51	0.18/0.04	1.444	3.129	47184/47185	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47185/47185	1.000
October 1 to 31, 2012								
Ch11 Mouse GSM High	29.3 to 32.9	10.00	10.02	0.19/0.05	3.290	12.620	48801/48802	1.000
Ch12 Mouse GSM Med	30.0 to 33.8	5.00	5.02	0.18/0.04	3.828	6.511	48801/48801	1.000
Ch14 Mouse GSM Low	29.2 to 32.7	2.50	2.51	0.17/0.04	2.017	3.080	48801/48801	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48801/48801	1.000
November 1 to 30, 2012								
Ch11 Mouse GSM High	32.9 to 36.6	10.00	10.03	0.19/0.04	7.649	13.824	47314/47314	1.000
Ch12 Mouse GSM Med	33.8 to 36.4	5.00	5.02	0.17/0.04	3.724	6.537	47314/47314	1.000
Ch14 Mouse GSM Low	32.7 to 35.8	2.50	2.51	0.17/0.04	2.054	3.110	47314/47314	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47314/47314	1.000
December 1 to 31, 2012								
Ch11 Mouse GSM High	36.6 to 39.1	10.00	10.07	0.20/0.05	7.992	12.863	48750/48750	1.000
Ch12 Mouse GSM Med	36.4 to 39.2	5.00	5.04	0.18/0.04	4.145	6.028	48748/48748	1.000
Ch14 Mouse GSM Low	35.8 to 38.1	2.50	2.52	0.17/0.04	2.139	3.109	48748/48748	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48748/48748	1.000
January 1 to 31, 2013								
Ch11 Mouse GSM High	39.1 to 41.1	10.00	9.78	0.30/0.07	7.230	13.516	48689/48689	1.000

Chamber	Weight Range [g]	Target [W/kg]	Mean [W/kg]	Stdev [dB]/[W/kg]	Min [W/kg]	Max [W/kg]	In Range/ Total	Ratio
Ch12 Mouse GSM Med	39.2 to 41.6	5.00	5.02	0.20/0.05	3.121	7.619	48681/48682	1.000
Ch14 Mouse GSM Low	38.1 to 40.6	2.50	2.51	0.17/0.04	2.037	2.987	48682/48682	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48682/48682	1.000
February 1 to 28, 2013								
Ch11 Mouse GSM High	41.1 to 42.9	10.00	8.23	0.22/0.05	6.187	10.364	44057/44058	1.000
Ch12 Mouse GSM Med	41.6 to 43.5	5.00	5.02	0.17/0.04	3.872	5.967	44058/44058	1.000
Ch14 Mouse GSM Low	40.6 to 42.2	2.50	2.52	0.17/0.04	1.851	3.048	44058/44058	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	44058/44058	1.000
March 1 to 31, 2013								
Ch11 Mouse GSM High	42.9 to 44.4	10.00	8.25	0.24/0.06	6.753	10.627	48892/48892	1.000
Ch12 Mouse GSM Med	43.5 to 44.7	5.00	5.04	0.17/0.04	4.276	5.871	48892/48892	1.000
Ch14 Mouse GSM Low	42.2 to 43.4	2.50	2.51	0.17/0.04	2.143	2.943	48892/48892	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48892/48892	1.000
April 1 to 30, 2013								
Ch11 Mouse GSM High	44.4 to 46.8	10.00	7.95	0.20/0.05	6.370	9.872	48130/48130	1.000
Ch12 Mouse GSM Med	44.7 to 47.3	5.00	5.02	0.17/0.04	4.113	5.862	48130/48130	1.000
Ch14 Mouse GSM Low	43.4 to 46.0	2.50	2.52	0.16/0.04	2.214	2.995	48130/48130	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48130/48130	1.000
May 1 to 31, 2013								
Ch11 Mouse GSM High	46.8 to 47.9	10.00	7.94	0.19/0.04	5.057	9.940	48509/48510	1.000
Ch12 Mouse GSM Med	47.3 to 48.7	5.00	5.01	0.17/0.04	3.264	7.176	48510/48510	1.000
Ch14 Mouse GSM Low	46.0 to 47.5	2.50	2.51	0.17/0.04	1.809	2.957	48510/48510	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48510/48510	1.000
June 1 to 30, 2013								
Ch11 Mouse GSM High	47.9 to 49.2	10.00	7.44	0.17/0.04	6.134	9.224	47246/47248	1.000
Ch12 Mouse GSM Med	48.7 to 49.9	5.00	5.01	0.17/0.04	4.185	5.911	47248/47248	1.000
Ch14 Mouse GSM Low	47.5 to 49.0	2.50	2.50	0.16/0.04	1.964	2.923	47248/47248	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47248/47248	1.000
July 1 to 31, 2013								
Ch11 Mouse GSM High	49.2 to 50.5	10.00	8.02	0.26/0.06	5.376	10.141	49496/49573	0.998
Ch12 Mouse GSM Med	49.9 to 51.5	5.00	5.01	0.17/0.04	3.448	5.910	49573/49573	1.000
Ch14 Mouse GSM Low	49.0 to 50.2	2.50	2.51	0.17/0.04	1.876	2.915	49573/49573	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	49573/49573	1.000
August 1 to 31, 2013								
Ch11 Mouse GSM High	50.5 to 51.3	10.00	8.33	0.22/0.05	6.666	10.172	50850/50850	1.000
Ch12 Mouse GSM Med	51.5 to 52.5	5.00	4.99	0.18/0.04	4.182	6.536	50850/50850	1.000
Ch14 Mouse GSM Low	50.2 to 51.3	2.50	2.50	0.17/0.04	2.065	3.317	50850/50850	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	50850/50850	1.000

Chamber	Weight Range [g]	Target [W/kg]	Mean [W/kg]	Stdev [dB]/[W/kg]	Min [W/kg]	Max [W/kg]	In Range/ Total	Ratio
September 1 to 30, 2013								
Ch11 Mouse GSM High	51.3 to 52.0	10.95	9.88	0.40/0.10	3.473	14.080	46959/46961	1.000
Ch12 Mouse GSM Med	52.5 to 53.2	5.00	5.01	0.18/0.04	4.292	5.988	46960/46960	1.000
Ch14 Mouse GSM Low	51.3 to 52.2	2.50	2.50	0.17/0.04	1.329	2.996	46956/46960	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	46960/46960	1.000
October 1 to 31, 2013								
Ch11 Mouse GSM High	52.0 to 53.3	10.95	10.83	0.22/0.05	6.969	14.792	50408/50408	1.000
Ch12 Mouse GSM Med	53.2 to 54.0	5.00	5.01	0.19/0.04	3.215	5.974	50408/50408	1.000
Ch14 Mouse GSM Low	52.2 to 53.0	2.50	2.50	0.16/0.04	1.669	3.009	50408/50408	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	50408/50408	1.000
November 1 to 30, 2013								
Ch11 Mouse GSM High	52.4 to 53.3	10.95	9.54	0.35/0.08	5.677	13.090	46609/46613	1.000
Ch12 Mouse GSM Med	53.1 to 54.0	5.00	4.96	0.24/0.06	2.923	7.086	46612/46613	1.000
Ch14 Mouse GSM Low	52.4 to 53.0	2.50	2.50	0.19/0.05	1.629	2.955	46613/46613	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	46613/46613	1.000
December 1 to 31, 2013								
Ch11 Mouse GSM High	51.4 to 52.4	10.95	10.22	0.36/0.09	7.156	13.073	48423/48423	1.000
Ch12 Mouse GSM Med	51.9 to 53.1	5.00	4.96	0.21/0.05	3.618	7.513	48423/48423	1.000
Ch14 Mouse GSM Low	51.1 to 52.4	2.50	2.50	0.18/0.04	1.475	4.060	48421/48423	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48423/48423	1.000
January 1 to 31, 2014								
Ch11 Mouse GSM High	51.4 to 52.1	10.95	10.08	0.27/0.06	6.308	13.144	48774/48775	1.000
Ch12 Mouse GSM Med	51.9 to 52.7	5.00	5.00	0.20/0.05	3.593	6.330	48775/48775	1.000
Ch14 Mouse GSM Low	51.1 to 51.6	2.50	2.50	0.18/0.04	0.472	3.843	48772/48775	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48775/48775	1.000
February 1 to 28, 2014								
Ch11 Mouse GSM High	52.1 to 53.2	10.95	10.92	0.24/0.06	8.258	15.024	44092/44092	1.000
Ch12 Mouse GSM Med	52.7 to 53.6	5.00	4.59	0.41/0.10	2.273	6.443	43990/44092	0.998
Ch14 Mouse GSM Low	51.6 to 53.1	2.50	2.50	0.18/0.04	1.622	3.807	44092/44092	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	44092/44092	1.000
March 1 to 31, 2014								
Ch11 Mouse GSM High	52.8 to 53.8	10.95	10.27	0.43/0.10	6.995	15.483	48571/48571	1.000
Ch12 Mouse GSM Med	53.3 to 53.8	5.00	4.56	0.60/0.15	2.706	6.677	47927/48571	0.987
Ch14 Mouse GSM Low	52.8 to 53.3	2.50	2.51	0.16/0.04	1.877	3.110	48571/48571	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48571/48571	1.000
April 1 to 30, 2014								
Ch11 Mouse GSM High	51.5 to 52.3	10.95	10.73	0.41/0.10	7.050	14.898	47274/47274	1.000
Ch12 Mouse GSM Med	53.0 to 53.4	5.00	4.92	0.66/0.16	2.581	8.007	46546/47274	0.985

Chamber	Weight Range [g]	Target [W/kg]	Mean [W/kg]	Stdev [dB]/[W/kg]	Min [W/kg]	Max [W/kg]	In Range/ Total	Ratio
Ch14 Mouse GSM Low	51.9 to 52.3	2.50	2.50	0.15/0.03	1.868	2.893	47274/47274	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47274/47274	1.000
May 1 to 31, 2014								
Ch11 Mouse GSM High	50.5 to 51.5	10.95	10.95	0.22/0.05	6.826	14.016	48620/48622	1.000
Ch12 Mouse GSM Med	51.3 to 53.0	5.00	5.00	0.22/0.05	2.622	7.487	48550/48622	0.999
Ch14 Mouse GSM Low	51.2 to 51.9	2.50	2.50	0.15/0.03	2.188	2.921	48622/48622	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48622/48622	1.000
June 1 to 30, 2014								
Ch11 Mouse GSM High	49.4 to 50.5	10.95	10.97	0.20/0.05	8.188	13.942	47144/47144	1.000
Ch12 Mouse GSM Med	50.8 to 51.3	5.00	5.01	0.16/0.04	3.005	5.830	47142/47144	1.000
Ch14 Mouse GSM Low	50.2 to 51.2	2.50	2.51	0.15/0.03	2.153	2.870	47144/47144	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47144/47144	1.000
July 1 to 9, 2014								
Ch11 Mouse GSM High	49.4 to 49.4	10.95	11.08	0.19/0.04	8.839	13.746	12532/12532	1.000
Ch12 Mouse GSM Med	50.8 to 50.8	5.00	5.02	0.15/0.04	4.488	5.844	12532/12532	1.000
Ch14 Mouse GSM Low	50.2 to 50.2	2.50	2.51	0.17/0.04	1.995	3.111	12532/12532	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	12532/12532	1.000
June 18, 2012, to July 9, 2014								
Ch11 Mouse GSM High	18.9 to 53.8	10.95	9.56	0.44/0.11	3.290	23.576	1136126/ 1136221	1.000
Ch12 Mouse GSM Med	18.9 to 54.0	5.00	4.97	0.29/0.07	2.105	11.918	1134656/ 1136208	0.999
Ch14 Mouse GSM Low	18.8 to 53.3	2.50	2.51	0.17/0.04	0.472	4.060	1136198/ 1136208	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	1136208/ 1136208	1.000

[a]Ch = chamber (e.g., Ch11 = Chamber 11).

Table I-2. Summary of GSM-modulated Cell Phone RFR Exposure Data—Chamber Field[a]

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
June 18 to 30, 2012							
Ch11 Mouse GSM High	194.10 to 199.60	197.33	0.23/5.27	121.76	297.71	38944/38950	1.000
Ch12 Mouse GSM Med	137.20 to 141.20	139.51	0.21/3.45	88.97	211.67	38944/38950	1.000
Ch14 Mouse GSM Low	97.00 to 99.80	98.42	0.20/2.26	88.09	109.25	38950/38950	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	38950/38950	1.000
July 1 to 31, 2012							
Ch11 Mouse GSM High	199.60 to 212.30	205.98	0.23/5.60	180.13	237.61	97462/97462	1.000
Ch12 Mouse GSM Med	141.20 to 150.10	145.84	0.21/3.55	119.12	174.30	97462/97462	1.000
Ch14 Mouse GSM Low	99.80 to 106.10	103.40	0.18/2.22	92.84	116.92	97462/97462	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97462/97462	1.000
August 1 to 31, 2012							
Ch11 Mouse GSM High	212.30 to 222.20	216.19	0.20/5.04	181.61	257.98	94976/94976	1.000
Ch12 Mouse GSM Med	150.10 to 157.10	154.16	0.20/3.67	136.80	180.42	94976/94976	1.000
Ch14 Mouse GSM Low	106.10 to 111.10	108.48	0.18/2.26	95.61	130.19	94976/94976	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94976/94976	1.000
September 1 to 30, 2012							
Ch11 Mouse GSM High	222.20 to 228.20	226.30	0.21/5.48	162.27	251.45	94372/94374	1.000
Ch12 Mouse GSM Med	157.10 to 161.40	160.65	0.19/3.49	115.42	179.26	94368/94370	1.000
Ch14 Mouse GSM Low	111.10 to 114.10	112.89	0.18/2.35	85.61	126.49	94368/94370	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94370/94370	1.000
October 1 to 31, 2012							
Ch11 Mouse GSM High	228.20 to 235.60	232.23	0.20/5.31	135.19	264.78	97602/97602	1.000
Ch12 Mouse GSM Med	161.40 to 168.00	165.17	0.18/3.51	141.20	191.80	97602/97602	1.000
Ch14 Mouse GSM Low	114.10 to 117.80	116.22	0.17/2.29	102.50	129.10	97602/97602	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97602/97602	1.000
November 1 to 30, 2012							
Ch11 Mouse GSM High	235.60 to 242.70	240.08	0.19/5.34	212.13	285.16	94628/94628	1.000
Ch12 Mouse GSM Med	168.00 to 171.70	170.49	0.17/3.37	145.05	192.18	94628/94628	1.000
Ch14 Mouse GSM Low	117.80 to 120.60	119.65	0.17/2.35	108.08	134.46	94628/94628	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94628/94628	1.000
December 1 to 31, 2012							
Ch11 Mouse GSM High	242.70 to 247.20	246.27	0.20/5.79	220.75	280.06	97500/97500	1.000
Ch12 Mouse GSM Med	171.70 to 174.80	174.25	0.18/3.56	158.98	191.03	97496/97496	1.000
Ch14 Mouse GSM Low	120.60 to 122.90	122.40	0.17/2.38	111.52	136.85	97496/97496	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97496/97496	1.000
January 1 to 31, 2013							
Ch11 Mouse GSM High	247.20 to 249.80	246.34	0.31/8.90	212.57	290.65	97378/97378	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch12 Mouse GSM Med	174.80 to 176.70	176.61	0.21/4.30	139.67	218.22	97362/97364	1.000
Ch14 Mouse GSM Low	122.90 to 124.30	124.22	0.17/2.39	112.14	135.78	97364/97364	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97364/97364	1.000
February 1 to 28, 2013							
Ch11 Mouse GSM High	249.80 to 251.10	227.29	0.25/6.60	197.26	254.51	88114/88116	1.000
Ch12 Mouse GSM Med	176.70 to 178.50	178.60	0.17/3.60	157.05	194.95	88116/88116	1.000
Ch14 Mouse GSM Low	124.30 to 125.60	125.67	0.17/2.43	107.89	138.45	88116/88116	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	88116/88116	1.000
March 1 to 31, 2013							
Ch11 Mouse GSM High	251.10 to 253.60	229.49	0.26/7.11	207.98	261.00	97784/97784	1.000
Ch12 Mouse GSM Med	178.50 to 179.30	179.57	0.17/3.62	165.02	193.99	97784/97784	1.000
Ch14 Mouse GSM Low	125.60 to 126.20	126.39	0.17/2.55	116.82	136.92	97784/97784	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97784/97784	1.000
April 1 to 30, 2013							
Ch11 Mouse GSM High	253.60 to 256.00	227.10	0.23/5.99	203.37	253.19	96260/96260	1.000
Ch12 Mouse GSM Med	179.30 to 181.80	180.58	0.18/3.69	163.42	195.38	96260/96260	1.000
Ch14 Mouse GSM Low	126.20 to 127.40	127.12	0.16/2.42	119.14	138.56	96260/96260	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	96260/96260	1.000
May 1 to 31, 2013							
Ch11 Mouse GSM High	256.00 to 257.20	227.85	0.21/5.62	181.80	254.88	97018/97020	1.000
Ch12 Mouse GSM Med	181.80 to 182.60	182.15	0.17/3.65	147.02	218.01	97020/97020	1.000
Ch14 Mouse GSM Low	127.40 to 128.60	127.68	0.17/2.51	108.39	138.57	97020/97020	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97020/97020	1.000
June 1 to 30, 2013							
Ch11 Mouse GSM High	257.20 to 259.40	222.18	0.20/5.26	202.90	247.16	94490/94496	1.000
Ch12 Mouse GSM Med	182.60 to 183.40	182.92	0.17/3.62	167.03	198.51	94496/94496	1.000
Ch14 Mouse GSM Low	128.60 to 129.10	128.74	0.16/2.39	114.06	139.13	94496/94496	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94496/94496	1.000
July 1 to 31, 2013							
Ch11 Mouse GSM High	259.40 to 260.60	232.30	0.29/7.92	189.95	261.63	98976/99146	0.998
Ch12 Mouse GSM Med	183.40 to 185.00	183.88	0.17/3.71	152.12	201.19	99146/99146	1.000
Ch14 Mouse GSM Low	129.10 to 130.30	129.63	0.17/2.54	111.83	140.17	99146/99146	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	99146/99146	1.000
August 1 to 31, 2013							
Ch11 Mouse GSM High	260.60 to 261.60	238.28	0.24/6.76	212.95	263.95	101700/101700	1.000
Ch12 Mouse GSM Med	185.00 to 185.80	185.04	0.18/3.97	169.82	211.58	101700/101700	1.000
Ch14 Mouse GSM Low	130.30 to 130.80	130.56	0.17/2.57	118.52	150.21	101700/101700	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	101700/101700	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
September 1 to 30, 2013							
Ch11 Mouse GSM High	261.60 to 273.80	259.49	0.42/12.99	154.24	310.55	93918/93922	1.000
Ch12 Mouse GSM Med	185.80 to 186.60	186.08	0.19/4.02	172.65	203.93	93920/93920	1.000
Ch14 Mouse GSM Low	130.80 to 131.40	131.14	0.17/2.55	95.42	143.74	93912/93920	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	93920/93920	1.000
October 1 to 31, 2013							
Ch11 Mouse GSM High	273.80 to 276.10	273.26	0.23/7.32	219.98	320.51	100816/100816	1.000
Ch12 Mouse GSM Med	186.60 to 186.60	186.50	0.19/4.08	149.42	203.69	100816/100816	1.000
Ch14 Mouse GSM Low	131.40 to 131.40	131.40	0.16/2.42	107.28	144.05	100816/100816	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	100816/100816	1.000
November 1 to 30, 2013							
Ch11 Mouse GSM High	275.00 to 276.10	256.54	0.37/11.29	197.87	301.50	93218/93226	1.000
Ch12 Mouse GSM Med	186.60 to 186.60	185.47	0.25/5.34	142.46	221.82	93224/93226	1.000
Ch14 Mouse GSM Low	131.40 to 131.40	131.34	0.20/3.01	106.00	142.76	93226/93226	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	93226/93226	1.000
December 1 to 31, 2013							
Ch11 Mouse GSM High	273.80 to 275.00	264.56	0.38/11.98	222.16	299.75	96846/96846	1.000
Ch12 Mouse GSM Med	185.00 to 186.60	184.56	0.21/4.62	157.41	228.42	96846/96846	1.000
Ch14 Mouse GSM Low	130.80 to 131.40	130.98	0.18/2.74	100.51	166.76	96842/96846	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	96846/96846	1.000
January 1 to 31, 2014							
Ch11 Mouse GSM High	273.80 to 275.00	263.34	0.29/8.82	208.57	301.08	97548/97550	1.000
Ch12 Mouse GSM Med	185.00 to 185.80	185.51	0.20/4.28	157.42	208.93	97550/97550	1.000
Ch14 Mouse GSM Low	130.80 to 130.80	130.79	0.18/2.80	56.85	162.24	97544/97550	1.000
Ch13 Mouse Sham	000.00 to 000.00	0.00	–/0.00	0.00	0.00	97550/97550	1.000
February 1 to 28, 2014							
Ch11 Mouse GSM High	275.00 to 276.10	275.23	0.24/7.74	239.47	323.01	88184/88184	1.000
Ch12 Mouse GSM Med	185.80 to 186.60	178.26	0.45/9.39	125.65	211.52	87980/88184	0.998
Ch14 Mouse GSM Low	130.80 to 131.90	131.73	0.18/2.73	106.14	162.60	88184/88184	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	88184/88184	1.000
March 1 to 31, 2014							
Ch11 Mouse GSM High	275.00 to 276.10	266.21	0.46/14.46	220.40	327.90	97142/97142	1.000
Ch12 Mouse GSM Med	186.60 to 186.60	177.33	0.67/14.20	137.09	215.33	95760/97142	0.986
Ch14 Mouse GSM Low	131.40 to 131.90	131.77	0.16/2.40	114.17	146.97	97142/97142	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97142/97142	1.000
April 1 to 30, 2014							
Ch11 Mouse GSM High	273.80 to 275.00	271.16	0.43/13.88	220.51	319.44	94548/94548	1.000
Ch12 Mouse GSM Med	185.80 to 186.60	184.10	0.70/15.37	133.88	235.80	93074/94548	0.984

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch14 Mouse GSM Low	130.80 to 131.40	131.27	0.15/2.29	113.50	141.25	94548/94548	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94548/94548	1.000
May 1 to 31, 2014							
Ch11 Mouse GSM High	272.70 to 273.80	273.60	0.23/7.40	216.22	309.84	97240/97244	1.000
Ch12 Mouse GSM Med	185.00 to 185.80	185.60	0.24/5.11	134.48	227.23	97098/97244	0.998
Ch14 Mouse GSM Low	130.80 to 130.80	130.87	0.15/2.24	122.41	141.45	97244/97244	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97244/97244	1.000
June 1 to 30, 2014							
Ch11 Mouse GSM High	271.50 to 272.70	272.64	0.20/6.44	236.01	307.96	94288/94288	1.000
Ch12 Mouse GSM Med	184.20 to 185.00	184.73	0.16/3.49	142.97	199.14	94286/94288	1.000
Ch14 Mouse GSM Low	130.30 to 130.80	130.94	0.15/2.22	121.45	140.21	94288/94288	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94288/94288	1.000
July 1 to 9, 2014							
Ch11 Mouse GSM High	271.50 to 271.50	272.57	0.19/5.96	243.57	303.74	25064/25064	1.000
Ch12 Mouse GSM Med	184.20 to 184.20	184.80	0.15/3.27	174.73	199.39	25064/25064	1.000
Ch14 Mouse GSM Low	130.30 to 130.30	130.69	0.17/2.66	116.49	145.47	25064/25064	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	25064/25064	1.000
June 18, 2012, to July 9, 2014							
Ch11 Mouse GSM High	194.10 to 276.10	244.10	0.48/13.78	121.76	327.90	2272234/ 2272442	1.000
Ch12 Mouse GSM Med	137.20 to 186.60	176.76	0.31/6.35	88.97	235.80	2269198/ 2272416	0.999
Ch14 Mouse GSM Low	97.00 to 131.90	125.14	0.17/2.48	56.85	166.76	2272396/ 2272416	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	2272416/ 2272416	1.000

[a]Ch = chamber (e.g., Ch11 = Chamber 11).

Table I-3. Summary of GSM-modulated Cell Phone RFR Exposure Data—E-Field[a]

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
June 18 to 30, 2012							
Ch11 Mouse GSM High	194.1 to 199.6	220.41	0.36/9.20	134.8	342.3	38908/38950	0.999
Ch12 Mouse GSM Med	137.2 to 141.2	148.22	0.31/5.41	93.1	224.6	38944/38950	1.000
Ch14 Mouse GSM Low	97.0 to 99.8	93.00	0.25/2.72	82.8	106.6	38950/38950	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	38950/38950	1.000
July 1 to 31, 2012							
Ch11 Mouse GSM High	199.6 to 212.3	232.54	0.37/10.25	191.3	275.5	97310/97462	0.998
Ch12 Mouse GSM Med	141.2 to 150.1	154.86	0.31/5.70	121.0	190.6	97460/97462	1.000
Ch14 Mouse GSM Low	99.8 to 106.1	96.90	0.23/2.66	85.6	111.1	97462/97462	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97462/97462	1.000
August 1 to 31, 2012							
Ch11 Mouse GSM High	212.3 to 222.2	249.45	0.37/10.92	204.4	315.0	94710/94976	0.997
Ch12 Mouse GSM Med	150.1 to 157.1	164.75	0.31/5.97	144.8	197.2	94968/94976	1.000
Ch14 Mouse GSM Low	106.1 to 111.1	101.69	0.23/2.69	89.1	120.4	94976/94976	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94976/94976	1.000
September 1 to 30, 2012							
Ch11 Mouse GSM High	222.2 to 228.2	267.26	0.37/11.47	193.8	317.6	93216/94374	0.988
Ch12 Mouse GSM Med	157.1 to 161.4	171.56	0.31/6.17	119.3	197.8	94366/94370	1.000
Ch14 Mouse GSM Low	114.1 to 117.8	110.31	0.25/3.25	94.8	125.7	94962/94962	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94962/94962	1.000
October 1 to 31, 2012							
Ch11 Mouse GSM High	228.2 to 235.6	270.30	0.36/11.39	161.2	317.0	97028/97604	0.994
Ch12 Mouse GSM Med	161.4 to 168.0	172.36	0.29/5.83	149.2	200.7	97602/97602	1.000
Ch14 Mouse GSM Low	114.1 to 117.8	110.32	0.25/3.26	94.8	125.7	97602/97602	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97602/97602	1.000
November 1 to 30, 2012							
Ch11 Mouse GSM High	235.6 to 242.7	280.59	0.36/11.92	236.7	351.9	93952/94628	0.993
Ch12 Mouse GSM Med	168.0 to 171.7	175.49	0.26/5.33	150.0	202.3	94628/94628	1.000
Ch14 Mouse GSM Low	117.8 to 120.6	112.89	0.23/3.09	99.2	127.3	94628/94628	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94628/94628	1.000
December 1 to 31, 2012							
Ch11 Mouse GSM High	242.7 to 247.2	291.82	0.38/13.01	253.5	340.0	95756/97500	0.982
Ch12 Mouse GSM Med	171.7 to 174.8	180.56	0.27/5.72	161.5	204.8	97496/97496	1.000
Ch14 Mouse GSM Low	120.6 to 122.9	117.17	0.24/3.25	104.1	133.5	97496/97496	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97496/97496	1.000
January 1 to 31, 2013							
Ch11 Mouse GSM High	247.2 to 249.8	285.35	0.64/21.65	229.0	359.4	96120/97378	0.987

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch12 Mouse GSM Med	174.8 to 176.7	183.63	0.30/6.49	148.1	233.4	97362/97364	1.000
Ch14 Mouse GSM Low	122.9 to 124.3	119.13	0.24/3.35	104.9	133.0	97364/97364	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97364/97364	1.000
February 1 to 28, 2013							
Ch11 Mouse GSM High	249.8 to 251.1	245.59	0.41/11.75	208.2	292.5	88116/88116	1.000
Ch12 Mouse GSM Med	176.7 to 178.5	187.59	0.28/6.15	161.8	212.4	88116/88116	1.000
Ch14 Mouse GSM Low	124.3 to 125.6	119.66	0.24/3.39	99.0	135.0	88114/88116	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	88116/88116	1.000
March 1 to 31, 2013							
Ch11 Mouse GSM High	251.1 to 253.6	248.20	0.40/11.68	213.4	298.3	97784/97784	1.000
Ch12 Mouse GSM Med	178.5 to 179.3	187.29	0.30/6.68	163.4	215.1	97784/97784	1.000
Ch14 Mouse GSM Low	125.6 to 126.2	121.50	0.25/3.56	109.2	138.8	97784/97784	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97784/97784	1.000
April 1 to 30, 2013							
Ch11 Mouse GSM High	253.6 to 256.0	245.75	0.37/10.67	206.0	283.6	96260/96260	1.000
Ch12 Mouse GSM Med	179.3 to 181.8	188.33	0.28/6.14	169.2	215.0	96260/96260	1.000
Ch14 Mouse GSM Low	126.2 to 127.4	119.94	0.24/3.42	106.9	134.6	96260/96260	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	96260/96260	1.000
May 1 to 31, 2013							
Ch11 Mouse GSM High	256.0 to 257.2	245.46	0.34/9.92	192.9	297.6	97018/97020	1.000
Ch12 Mouse GSM Med	181.8 to 182.6	184.92	0.36/7.72	154.7	219.8	97020/97020	1.000
Ch14 Mouse GSM Low	127.4 to 128.6	123.25	0.25/3.53	101.9	137.4	97020/97020	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97020/97020	1.000
June 1 to 30, 2013							
Ch11 Mouse GSM High	257.2 to 259.4	238.55	0.31/8.53	208.8	277.6	94496/94496	1.000
Ch12 Mouse GSM Med	182.6 to 183.4	180.20	0.27/5.60	160.4	204.7	94496/94496	1.000
Ch14 Mouse GSM Low	128.6 to 129.1	122.13	0.22/3.17	106.8	134.2	94496/94496	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94496/94496	1.000
July 1 to 31, 2013							
Ch11 Mouse GSM High	259.4 to 260.6	252.77	0.48/14.26	209.6	302.8	99146/99146	1.000
Ch12 Mouse GSM Med	183.4 to 185.0	180.18	0.26/5.54	149.9	202.6	99146/99146	1.000
Ch14 Mouse GSM Low	129.1 to 130.3	122.67	0.24/3.49	99.9	137.4	99144/99146	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	99146/99146	1.000
August 1 to 31, 2013							
Ch11 Mouse GSM High	260.6 to 261.6	238.13	0.36/10.20	205.2	287.5	101698/101700	1.000
Ch12 Mouse GSM Med	185.0 to 185.8	180.96	0.29/6.22	160.7	210.2	101700/101700	1.000
Ch14 Mouse GSM Low	130.3 to 130.8	124.66	0.25/3.62	109.9	141.5	101700/101700	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	101700/101700	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
September 1 to 30, 2013							
Ch11 Mouse GSM High	261.6 to 273.8	251.71	0.43/12.83	161.3	311.1	93890/93922	1.000
Ch12 Mouse GSM Med	185.8 to 186.6	181.55	0.28/5.84	159.1	205.9	93920/93920	1.000
Ch14 Mouse GSM Low	130.8 to 131.4	124.86	0.25/3.59	89.3	140.0	93912/93920	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	93920/93920	1.000
October 1 to 31, 2013							
Ch11 Mouse GSM High	273.8 to 276.1	264.68	0.29/9.12	209.0	306.5	100814/100816	1.000
Ch12 Mouse GSM Med	186.6 to 186.6	182.15	0.28/5.91	145.4	205.6	100814/100816	1.000
Ch14 Mouse GSM Low	131.4 to 131.4	123.98	0.24/3.55	105.9	138.5	100816/100816	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	100816/100816	1.000
November 1 to 30, 2013							
Ch11 Mouse GSM High	275.0 to 276.1	257.28	0.39/11.82	206.1	315.3	93220/93226	1.000
Ch12 Mouse GSM Med	186.6 to 186.6	184.13	0.34/7.34	135.2	228.1	93216/93226	1.000
Ch14 Mouse GSM Low	131.4 to 131.4	126.40	0.28/4.12	100.9	141.5	93198/93226	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	93226/93226	1.000
December 1 to 31, 2013							
Ch11 Mouse GSM High	273.8 to 275.0	265.70	0.39/12.26	214.7	308.3	96844/96846	1.000
Ch12 Mouse GSM Med	185.0 to 186.6	179.76	0.29/6.11	155.1	224.0	96846/96846	1.000
Ch14 Mouse GSM Low	130.8 to 131.4	122.89	0.25/3.62	95.3	152.2	96842/96846	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	96846/96846	1.000
January 1 to 31, 2014							
Ch11 Mouse GSM High	273.8 to 275.0	266.12	0.43/13.48	208.2	324.0	97548/97550	1.000
Ch12 Mouse GSM Med	185.0 to 185.8	180.59	0.27/5.78	156.4	207.5	97550/97550	1.000
Ch14 Mouse GSM Low	130.8 to 130.8	123.43	0.25/3.65	54.4	157.5	97538/97550	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97550/97550	1.000
February 1 to 28, 2014							
Ch11 Mouse GSM High	275.0 to 276.1	285.13	0.43/14.31	235.0	380.5	88182/88184	1.000
Ch12 Mouse GSM Med	185.8 to 186.6	182.81	0.38/8.21	125.8	214.8	88086/88184	0.999
Ch14 Mouse GSM Low	130.8 to 131.9	123.35	0.24/3.44	103.5	152.6	88180/88184	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	88184/88184	1.000
March 1 to 31, 2014							
Ch11 Mouse GSM High	275.0 to 276.1	261.60	0.57/17.65	199.8	325.6	96810/97142	0.997
Ch12 Mouse GSM Med	186.6 to 186.6	178.89	0.67/14.44	138.6	218.0	96626/97142	0.995
Ch14 Mouse GSM Low	131.4 to 131.9	124.02	0.24/3.40	105.7	138.7	97142/97142	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97142/97142	1.000
April 1 to 30, 2014							
Ch11 Mouse GSM High	273.8 to 275.0	264.65	0.57/18.01	203.2	327.8	94118/94548	0.995
Ch12 Mouse GSM Med	185.8 to 186.6	182.58	0.71/15.58	129.0	246.4	93222/94548	0.986

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch14 Mouse GSM Low	130.8 to 131.4	122.29	0.23/3.35	106.3	141.5	94548/94548	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94548/94548	1.000
May 1 to 31, 2014							
Ch11 Mouse GSM High	272.7 to 273.8	268.70	0.37/11.81	201.7	319.0	97086/97244	0.998
Ch12 Mouse GSM Med	185.0 to 185.8	184.59	0.34/7.30	131.9	223.2	97154/97244	0.999
Ch14 Mouse GSM Low	130.8 to 130.8	122.38	0.23/3.30	108.2	136.7	97244/97244	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97244/97244	1.000
June 1 to 30, 2014							
Ch11 Mouse GSM High	271.5 to 272.7	275.38	0.41/13.20	222.4	327.6	94288/94288	1.000
Ch12 Mouse GSM Med	184.2 to 185.0	180.65	0.26/5.58	141.8	202.2	94282/94288	1.000
Ch14 Mouse GSM Low	130.3 to 130.8	123.72	0.23/3.37	110.5	137.5	94288/94288	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94288/94288	1.000
July 1 to 9, 2014							
Ch11 Mouse GSM High	271.5 to 271.5	281.98	0.27/8.95	242.7	312.4	25064/25064	1.000
Ch12 Mouse GSM Med	184.2 to 184.2	185.84	0.22/4.78	169.6	201.3	25064/25064	1.000
Ch14 Mouse GSM Low	130.3 to 130.3	125.14	0.23/3.34	113.1	138.1	25064/25064	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	25064/25064	1.000
June 18, 2012, to July 9, 2014							
Ch11 Mouse GSM High	194.1 to 276.1	259.29	0.88/27.75	134.8	380.5	2265600/ 2272442	0.997
Ch12 Mouse GSM Med	137.2 to 186.6	179.13	0.47/9.94	93.1	246.4	2270352/ 2272416	0.999
Ch14 Mouse GSM Low	97.0 to 131.9	118.53	0.26/3.55	54.4	157.5	2272352/ 2272416	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	2272416/ 2272416	1.000

[a]Ch = chamber (e.g., Ch11 = Chamber 11).

Table I-4. Summary of GSM-modulated Cell Phone RFR Exposure Data—H-Field[a]

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
June 18 to 30, 2012							
Ch11 Mouse GSM High	0.52 to 0.53	0.462	0.26/0.014	0.29	0.67	38922/38950	0.999
Ch12 Mouse GSM Med	0.36 to 0.38	0.347	0.27/0.011	0.23	0.53	38944/38950	1.000
Ch14 Mouse GSM Low	0.26 to 0.27	0.275	0.29/0.009	0.25	0.31	38950/38950	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	38950/38950	1.000
July 1 to 31, 2012							
Ch11 Mouse GSM High	0.53 to 0.56	0.476	0.33/0.018	0.40	0.57	96830/97462	0.994
Ch12 Mouse GSM Med	0.38 to 0.40	0.363	0.25/0.011	0.30	0.42	97458/97462	1.000
Ch14 Mouse GSM Low	0.27 to 0.28	0.292	0.27/0.009	0.26	0.33	97462/97462	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97462/97462	1.000
August 1 to 31, 2012							
Ch11 Mouse GSM High	0.56 to 0.59	0.485	0.29/0.017	0.40	0.56	93530/94976	0.985
Ch12 Mouse GSM Med	0.40 to 0.42	0.381	0.25/0.011	0.33	0.45	94976/94976	1.000
Ch14 Mouse GSM Low	0.28 to 0.30	0.306	0.26/0.009	0.27	0.37	94976/94976	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94976/94976	1.000
September 1 to 30, 2012							
Ch11 Mouse GSM High	0.59 to 0.61	0.492	0.26/0.015	0.35	0.55	88558/94374	0.938
Ch12 Mouse GSM Med	0.42 to 0.43	0.397	0.25/0.012	0.30	0.45	94362/94370	1.000
Ch14 Mouse GSM Low	0.30 to 0.30	0.316	0.26/0.009	0.25	0.36	94370/94370	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94370/94370	1.000
October 1 to 31, 2012							
Ch11 Mouse GSM High	0.61 to 0.63	0.515	0.25/0.015	0.29	0.58	95516/97604	0.979
Ch12 Mouse GSM Med	0.43 to 0.45	0.419	0.25/0.012	0.34	0.49	97602/97602	1.000
Ch14 Mouse GSM Low	0.30 to 0.31	0.324	0.26/0.010	0.28	0.36	97602/97602	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97602/97602	1.000
November 1 to 30, 2012							
Ch11 Mouse GSM High	0.63 to 0.64	0.529	0.25/0.015	0.47	0.61	91670/94628	0.969
Ch12 Mouse GSM Med	0.45 to 0.46	0.439	0.24/0.012	0.37	0.49	94628/94628	1.000
Ch14 Mouse GSM Low	0.31 to 0.32	0.335	0.26/0.010	0.29	0.38	94628/94628	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94628/94628	1.000
December 1 to 31, 2012							
Ch11 Mouse GSM High	0.64 to 0.66	0.532	0.24/0.015	0.47	0.60	90788/97500	0.931
Ch12 Mouse GSM Med	0.46 to 0.46	0.445	0.23/0.012	0.40	0.50	97496/97496	1.000
Ch14 Mouse GSM Low	0.32 to 0.33	0.339	0.25/0.010	0.29	0.38	97496/97496	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97496/97496	1.000
January 1 to 31, 2013							
Ch11 Mouse GSM High	0.66 to 0.66	0.550	0.32/0.021	0.46	0.63	91600/97378	0.941

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch12 Mouse GSM Med	0.46 to 0.47	0.450	0.28/0.015	0.35	0.54	97286/97364	0.999
Ch14 Mouse GSM Low	0.33 to 0.33	0.343	0.25/0.010	0.31	0.39	97364/97364	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97364/97364	1.000
February 1 to 28, 2013							
Ch11 Mouse GSM High	0.66 to 0.67	0.554	0.23/0.015	0.49	0.62	86086/88116	0.977
Ch12 Mouse GSM Med	0.47 to 0.47	0.450	0.22/0.012	0.40	0.50	88116/88116	1.000
Ch14 Mouse GSM Low	0.33 to 0.33	0.349	0.24/0.010	0.29	0.39	88116/88116	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	88116/88116	1.000
March 1 to 31, 2013							
Ch11 Mouse GSM High	0.67 to 0.67	0.559	0.25/0.016	0.49	0.63	94850/97784	0.970
Ch12 Mouse GSM Med	0.47 to 0.48	0.456	0.25/0.013	0.40	0.52	97784/97784	1.000
Ch14 Mouse GSM Low	0.33 to 0.34	0.348	0.24/0.010	0.31	0.39	97784/97784	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97784/97784	1.000
April 1 to 30, 2013							
Ch11 Mouse GSM High	0.67 to 0.68	0.553	0.21/0.014	0.49	0.62	91198/96260	0.947
Ch12 Mouse GSM Med	0.48 to 0.48	0.458	0.22/0.012	0.40	0.50	96260/96260	1.000
Ch14 Mouse GSM Low	0.34 to 0.34	0.356	0.26/0.011	0.31	0.39	96260/96260	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	96260/96260	1.000
May 1 to 31, 2013							
Ch11 Mouse GSM High	0.68 to 0.68	0.558	0.22/0.014	0.45	0.62	92216/97020	0.950
Ch12 Mouse GSM Med	0.48 to 0.48	0.476	0.33/0.018	0.37	0.58	97018/97020	1.000
Ch14 Mouse GSM Low	0.34 to 0.34	0.350	0.25/0.010	0.31	0.39	97020/97020	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97020/97020	1.000
June 1 to 30, 2013							
Ch11 Mouse GSM High	0.68 to 0.69	0.546	0.23/0.015	0.48	0.60	81918/94496	0.867
Ch12 Mouse GSM Med	0.48 to 0.49	0.492	0.25/0.014	0.45	0.56	94496/94496	1.000
Ch14 Mouse GSM Low	0.34 to 0.34	0.359	0.24/0.010	0.32	0.39	94496/94496	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94496/94496	1.000
July 1 to 31, 2013							
Ch11 Mouse GSM High	0.69 to 0.69	0.562	0.25/0.016	0.45	0.63	92320/99146	0.931
Ch12 Mouse GSM Med	0.49 to 0.49	0.498	0.25/0.014	0.41	0.55	99146/99146	1.000
Ch14 Mouse GSM Low	0.34 to 0.35	0.362	0.26/0.011	0.32	0.40	99146/99146	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	99146/99146	1.000
August 1 to 31, 2013							
Ch11 Mouse GSM High	0.69 to 0.69	0.632	0.45/0.034	0.51	0.78	101140/101700	0.994
Ch12 Mouse GSM Med	0.49 to 0.49	0.502	0.27/0.016	0.44	0.58	101700/101700	1.000
Ch14 Mouse GSM Low	0.35 to 0.35	0.362	0.26/0.011	0.32	0.43	101700/101700	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	101700/101700	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
September 1 to 30, 2013							
Ch11 Mouse GSM High	0.69 to 0.73	0.709	0.53/0.044	0.39	0.88	93920/93922	1.000
Ch12 Mouse GSM Med	0.49 to 0.50	0.506	0.27/0.016	0.46	0.58	93920/93920	1.000
Ch14 Mouse GSM Low	0.35 to 0.35	0.365	0.25/0.011	0.27	0.40	93914/93920	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	93920/93920	1.000
October 1 to 31, 2013							
Ch11 Mouse GSM High	0.73 to 0.73	0.748	0.38/0.033	0.61	0.89	100816/100816	1.000
Ch12 Mouse GSM Med	0.50 to 0.50	0.506	0.27/0.016	0.41	0.59	100816/100816	1.000
Ch14 Mouse GSM Low	0.35 to 0.35	0.368	0.26/0.011	0.29	0.43	100816/100816	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	100816/100816	1.000
November 1 to 30, 2013							
Ch11 Mouse GSM High	0.73 to 0.73	0.679	0.44/0.036	0.49	0.83	93208/93226	1.000
Ch12 Mouse GSM Med	0.50 to 0.50	0.496	0.29/0.017	0.40	0.60	93226/93226	1.000
Ch14 Mouse GSM Low	0.35 to 0.35	0.361	0.28/0.012	0.28	0.41	93226/93226	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	93226/93226	1.000
December 1 to 31, 2013							
Ch11 Mouse GSM High	0.73 to 0.73	0.699	0.48/0.040	0.56	0.82	96800/96846	1.000
Ch12 Mouse GSM Med	0.49 to 0.50	0.502	0.31/0.018	0.41	0.62	96846/96846	1.000
Ch14 Mouse GSM Low	0.35 to 0.35	0.369	0.26/0.011	0.28	0.48	96844/96846	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	96846/96846	1.000
January 1 to 31, 2014							
Ch11 Mouse GSM High	0.73 to 0.73	0.691	0.32/0.026	0.55	0.82	97548/97550	1.000
Ch12 Mouse GSM Med	0.49 to 0.49	0.505	0.27/0.016	0.41	0.58	97550/97550	1.000
Ch14 Mouse GSM Low	0.35 to 0.35	0.366	0.26/0.011	0.16	0.44	97538/97550	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97550/97550	1.000
February 1 to 28, 2014							
Ch11 Mouse GSM High	0.73 to 0.73	0.704	0.35/0.029	0.59	0.82	88184/88184	1.000
Ch12 Mouse GSM Med	0.49 to 0.50	0.461	0.68/0.038	0.32	0.57	87662/88184	0.994
Ch14 Mouse GSM Low	0.35 to 0.35	0.372	0.25/0.011	0.29	0.46	88176/88184	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	88184/88184	1.000
March 1 to 31, 2014							
Ch11 Mouse GSM High	0.73 to 0.73	0.718	0.48/0.041	0.59	0.88	97142/97142	1.000
Ch12 Mouse GSM Med	0.50 to 0.50	0.466	0.74/0.041	0.33	0.59	93996/97142	0.968
Ch14 Mouse GSM Low	0.35 to 0.35	0.370	0.23/0.010	0.33	0.41	97142/97142	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97142/97142	1.000
April 1 to 30, 2014							
Ch11 Mouse GSM High	0.73 to 0.73	0.737	0.46/0.040	0.60	0.88	94548/94548	1.000
Ch12 Mouse GSM Med	0.49 to 0.50	0.492	0.81/0.048	0.34	0.68	92916/94548	0.983

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch14 Mouse GSM Low	0.35 to 0.35	0.372	0.24/0.010	0.32	0.41	94548/94548	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94548/94548	1.000
May 1 to 31, 2014							
Ch11 Mouse GSM High	0.72 to 0.73	0.739	0.34/0.030	0.60	0.85	97244/97244	1.000
Ch12 Mouse GSM Med	0.49 to 0.49	0.495	0.33/0.019	0.36	0.61	97052/97244	0.998
Ch14 Mouse GSM Low	0.35 to 0.35	0.370	0.22/0.010	0.34	0.41	97244/97244	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97244/97244	1.000
June 1 to 30, 2014							
Ch11 Mouse GSM High	0.72 to 0.72	0.716	0.36/0.031	0.63	0.84	94288/94288	1.000
Ch12 Mouse GSM Med	0.49 to 0.49	0.501	0.25/0.015	0.38	0.55	94284/94288	1.000
Ch14 Mouse GSM Low	0.35 to 0.35	0.366	0.23/0.010	0.33	0.40	94288/94288	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94288/94288	1.000
July 1 to 9, 2014							
Ch11 Mouse GSM High	0.72 to 0.72	0.698	0.26/0.021	0.63	0.78	25064/25064	1.000
Ch12 Mouse GSM Med	0.49 to 0.49	0.487	0.23/0.013	0.45	0.54	25064/25064	1.000
Ch14 Mouse GSM Low	0.35 to 0.35	0.361	0.26/0.011	0.32	0.41	25064/25064	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	25064/25064	1.000
June 18, 2012, to July 9, 2014							
Ch11 Mouse GSM High	0.52 to 0.73	0.607	0.73/0.053	0.29	0.89	2212122/ 2272442	0.973
Ch12 Mouse GSM Med	0.36 to 0.50	0.463	0.46/0.025	0.23	0.68	2266828/ 2272416	0.998
Ch14 Mouse GSM Low	0.26 to 0.35	0.349	0.26/0.011	0.16	0.48	2272388/ 2272416	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	2272416/ 2272416	1.000

[a]Ch = chamber (e.g., Ch11 = Chamber 11).

Table I-5. Summary of CDMA-modulated Cell Phone RFR Exposure Data—SAR[a]

Chamber	Weight Range [g]	Target [W/kg]	Mean [W/kg]	Stdev [dB]/[W/kg]	Min [W/kg]	Max [W/kg]	In Range/ Total	Ratio
June 18 to 30, 2012								
Ch01 Mouse IS95 High	18.9 to 20.2	10.00	9.98	0.13/0.03	5.483	20.437	19472/19475	1.000
Ch02 Mouse IS95 Med	18.9 to 20.2	5.00	4.94	0.17/0.04	3.641	7.729	19475/19475	1.000
Ch03 Mouse IS95 Low	18.9 to 20.1	2.50	2.49	0.11/0.03	2.134	3.273	19475/19475	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	19475/19475	1.000
July 1 to 31, 2012								
Ch01 Mouse IS95 High	20.2 to 24.6	10.00	9.98	0.12/0.03	6.703	16.201	48730/48731	1.000
Ch02 Mouse IS95 Med	20.2 to 24.6	5.00	4.96	0.15/0.04	3.476	8.609	48730/48731	1.000
Ch03 Mouse IS95 Low	20.1 to 24.7	2.50	2.49	0.11/0.03	1.742	4.180	48730/48731	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48731/48731	1.000
August 1 to 31, 2012								
Ch01 Mouse IS95 High	24.6 to 28.0	10.00	9.98	0.12/0.03	8.349	13.937	47488/47488	1.000
Ch02 Mouse IS95 Med	24.6 to 27.6	5.00	4.96	0.14/0.03	4.115	9.356	47487/47488	1.000
Ch03 Mouse IS95 Low	24.7 to 27.6	2.50	2.49	0.11/0.03	2.031	3.689	47488/47488	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47488/47488	1.000
September 1 to 30, 2012								
Ch01 Mouse IS95 High	28.0 to 30.1	10.00	9.98	0.11/0.03	8.923	11.261	47187/47187	1.000
Ch02 Mouse IS95 Med	27.6 to 29.3	5.00	4.96	0.13/0.03	4.325	6.682	47187/47187	1.000
Ch03 Mouse IS95 Low	27.6 to 29.1	2.50	2.49	0.11/0.03	2.180	2.844	47187/47187	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47185/47185	1.000
October 1 to 31, 2012								
Ch01 Mouse IS95 High	30.1 to 33.3	10.00	9.97	0.11/0.03	8.718	11.420	48802/48802	1.000
Ch02 Mouse IS95 Med	29.3 to 32.6	5.00	4.98	0.13/0.03	4.296	5.798	48802/48802	1.000
Ch03 Mouse IS95 Low	29.1 to 32.4	2.50	2.49	0.10/0.02	2.208	2.766	48802/48802	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48801/48801	1.000
November 1 to 30, 2012								
Ch01 Mouse IS95 High	33.3 to 36.7	10.00	9.98	0.11/0.03	4.470	11.321	47313/47314	1.000
Ch02 Mouse IS95 Med	32.6 to 36.1	5.00	4.98	0.13/0.03	2.462	5.974	47313/47314	1.000
Ch03 Mouse IS95 Low	32.4 to 35.5	2.50	2.49	0.11/0.03	1.174	2.967	47313/47314	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47314/47314	1.000
December 1 to 31, 2012								
Ch01 Mouse IS95 High	36.7 to 39.1	10.00	10.01	0.11/0.03	8.925	11.723	48750/48750	1.000
Ch02 Mouse IS95 Med	36.1 to 38.5	5.00	4.98	0.13/0.03	4.364	6.018	48750/48750	1.000
Ch03 Mouse IS95 Low	35.5 to 38.2	2.50	2.50	0.11/0.03	2.227	2.909	48750/48750	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48748/48748	1.000
January 1 to 31, 2013								
Ch01 Mouse IS95 High	39.1 to 41.1	10.00	9.98	0.12/0.03	8.549	11.885	48689/48689	1.000

Chamber	Weight Range [g]	Target [W/kg]	Mean [W/kg]	Stdev [dB]/[W/kg]	Min [W/kg]	Max [W/kg]	In Range/ Total	Ratio
Ch02 Mouse IS95 Med	38.5 to 40.8	5.00	4.98	0.13/0.03	4.218	5.822	48689/48689	1.000
Ch03 Mouse IS95 Low	38.2 to 40.8	2.50	2.50	0.11/0.03	2.161	2.957	48689/48689	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48682/48682	1.000
February 1 to 28, 2013								
Ch01 Mouse IS95 High	41.1 to 43.1	10.00	9.98	0.12/0.03	8.591	11.811	44058/44058	1.000
Ch02 Mouse IS95 Med	40.8 to 42.7	5.00	4.99	0.14/0.03	3.890	7.124	44058/44058	1.000
Ch03 Mouse IS95 Low	40.8 to 42.6	2.50	2.50	0.11/0.03	2.117	3.036	44058/44058	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	44058/44058	1.000
March 1 to 31, 2013								
Ch01 Mouse IS95 High	43.1 to 44.9	10.00	10.01	0.12/0.03	8.731	11.338	48892/48892	1.000
Ch02 Mouse IS95 Med	42.7 to 44.3	5.00	5.00	0.14/0.03	4.271	6.209	48892/48892	1.000
Ch03 Mouse IS95 Low	42.6 to 44.0	2.50	2.50	0.11/0.03	2.213	2.833	48892/48892	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48892/48892	1.000
April 1 to 30, 2013								
Ch01 Mouse IS95 High	44.9 to 47.8	10.00	10.00	0.12/0.03	8.512	12.723	48130/48130	1.000
Ch02 Mouse IS95 Med	44.3 to 47.5	5.00	4.98	0.14/0.03	4.329	5.899	48130/48130	1.000
Ch03 Mouse IS95 Low	44.0 to 47.2	2.50	2.49	0.12/0.03	2.196	2.858	48130/48130	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48130/48130	1.000
May 1 to 31, 2013								
Ch01 Mouse IS95 High	47.8 to 49.2	10.00	9.99	0.14/0.03	7.772	12.345	48510/48510	1.000
Ch02 Mouse IS95 Med	47.5 to 49.1	5.00	4.97	0.14/0.03	4.225	6.364	48510/48510	1.000
Ch03 Mouse IS95 Low	47.2 to 48.5	2.50	2.49	0.12/0.03	2.170	3.006	48510/48510	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48510/48510	1.000
June 1 to 30, 2013								
Ch01 Mouse IS95 High	49.2 to 50.4	10.00	10.02	0.15/0.03	7.714	12.935	47257/47257	1.000
Ch02 Mouse IS95 Med	49.1 to 50.4	5.00	4.99	0.14/0.03	4.037	6.047	47257/47257	1.000
Ch03 Mouse IS95 Low	48.5 to 50.2	2.50	2.50	0.25/0.06	1.455	3.737	47253/47257	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47248/47248	1.000
July 1 to 31, 2013								
Ch01 Mouse IS95 High	50.4 to 51.6	10.00	9.99	0.16/0.04	7.808	13.620	49573/49573	1.000
Ch02 Mouse IS95 Med	50.4 to 51.7	5.00	4.97	0.14/0.03	4.158	6.040	49573/49573	1.000
Ch03 Mouse IS95 Low	50.2 to 51.4	2.50	2.50	0.28/0.07	1.626	3.683	49573/49573	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	49573/49573	1.000
August 1 to 31, 2013								
Ch01 Mouse IS95 High	51.6 to 52.2	10.00	9.99	0.14/0.03	7.168	12.173	50856/50856	1.000
Ch02 Mouse IS95 Med	51.7 to 52.7	5.00	4.99	0.16/0.04	4.279	6.445	50856/50856	1.000
Ch03 Mouse IS95 Low	51.3 to 52.2	2.50	2.50	0.14/0.03	1.851	3.071	50856/50856	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	50850/50850	1.000

Chamber	Weight Range [g]	Target [W/kg]	Mean [W/kg]	Stdev [dB]/[W/kg]	Min [W/kg]	Max [W/kg]	In Range/ Total	Ratio
September 1 to 30, 2013								
Ch01 Mouse IS95 High	52.2 to 53.0	10.95	10.11	0.14/0.03	8.045	13.922	46961/46961	1.000
Ch02 Mouse IS95 Med	52.7 to 53.5	5.00	5.00	0.15/0.03	4.143	6.336	46961/46961	1.000
Ch03 Mouse IS95 Low	52.2 to 53.4	2.50	2.51	0.35/0.08	1.262	4.130	46946/46961	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	46960/46960	1.000
October 1 to 31, 2013								
Ch01 Mouse IS95 High	53.0 to 53.8	10.00	10.03	0.13/0.03	8.027	12.009	50408/50408	1.000
Ch02 Mouse IS95 Med	53.5 to 54.2	5.00	4.99	0.15/0.03	4.224	6.669	50408/50408	1.000
Ch03 Mouse IS95 Low	53.4 to 54.1	2.50	2.50	0.16/0.04	1.718	3.359	50408/50408	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	50408/50408	1.000
November 1 to 30, 2013								
Ch01 Mouse IS95 High	53.8 to 54.0	10.00	10.03	0.15/0.04	4.536	12.268	46637/46639	1.000
Ch02 Mouse IS95 Med	54.2 to 54.2	5.00	4.98	0.16/0.04	2.225	6.187	46637/46639	1.000
Ch03 Mouse IS95 Low	53.8 to 54.1	2.50	2.48	0.27/0.06	0.161	4.469	46551/46639	0.998
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	46613/46613	1.000
December 1 to 31, 2013								
Ch01 Mouse IS95 High	52.3 to 54.0	10.00	10.02	0.14/0.03	7.143	14.712	48423/48423	1.000
Ch02 Mouse IS95 Med	52.8 to 54.2	5.00	4.99	0.16/0.04	3.949	7.068	48423/48423	1.000
Ch03 Mouse IS95 Low	52.6 to 53.8	2.50	2.50	0.14/0.03	1.989	3.035	48423/48423	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48423/48423	1.000
January 1 to 31, 2014								
Ch01 Mouse IS95 High	52.3 to 52.7	10.00	9.99	0.14/0.03	6.121	14.242	48776/48777	1.000
Ch02 Mouse IS95 Med	52.8 to 53.4	5.00	5.00	0.15/0.04	1.378	6.481	48775/48777	1.000
Ch03 Mouse IS95 Low	52.6 to 53.0	2.50	2.51	0.31/0.07	0.429	4.110	48768/48776	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48775/48775	1.000
February 1 to 28, 2014								
Ch01 Mouse IS95 High	52.7 to 54.1	10.00	9.95	0.13/0.03	6.403	13.519	44092/44092	1.000
Ch02 Mouse IS95 Med	53.4 to 54.8	5.00	4.98	0.16/0.04	2.326	9.889	44085/44092	1.000
Ch03 Mouse IS95 Low	53.0 to 54.6	2.50	2.48	0.35/0.08	1.358	3.784	44059/44092	0.999
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	44092/44092	1.000
March 1 to 31, 2014								
Ch01 Mouse IS95 High	53.0 to 54.1	10.00	9.45	0.48/0.12	0.124	18.080	48470/48590	0.998
Ch02 Mouse IS95 Med	53.8 to 54.9	5.00	5.00	0.16/0.04	2.146	9.590	48585/48590	1.000
Ch03 Mouse IS95 Low	54.2 to 54.7	2.50	2.47	0.35/0.08	0.607	6.319	48505/48590	0.998
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48571/48571	1.000
April 1 to 30, 2014								
Ch01 Mouse IS95 High	51.8 to 52.8	10.00	9.96	0.21/0.05	0.435	21.444	47241/47275	0.999
Ch02 Mouse IS95 Med	52.9 to 53.2	5.00	5.02	0.21/0.05	0.771	12.768	47238/47275	0.999

Chamber	Weight Range [g]	Target [W/kg]	Mean [W/kg]	Stdev [dB]/[W/kg]	Min [W/kg]	Max [W/kg]	In Range/ Total	Ratio
Ch03 Mouse IS95 Low	53.3 to 53.8	2.50	2.48	0.27/0.06	0.656	3.495	47261/47275	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47274/47274	1.000
May 1 to 31, 2014								
Ch01 Mouse IS95 High	51.0 to 51.8	10.00	9.98	0.14/0.03	8.159	12.373	48622/48622	1.000
Ch02 Mouse IS95 Med	51.4 to 52.9	5.00	5.00	0.14/0.03	3.701	6.542	48622/48622	1.000
Ch03 Mouse IS95 Low	52.2 to 53.3	2.50	2.49	0.27/0.06	1.281	3.566	48619/48622	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	48622/48622	1.000
June 1 to 30, 2014								
Ch01 Mouse IS95 High	50.5 to 51.2	10.00	9.97	0.13/0.03	7.103	12.077	47144/47144	1.000
Ch02 Mouse IS95 Med	51.0 to 51.4	5.00	5.00	0.14/0.03	3.476	6.143	47144/47144	1.000
Ch03 Mouse IS95 Low	50.6 to 52.2	2.50	2.49	0.28/0.07	1.038	4.032	47132/47144	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	47144/47144	1.000
July 1 to 9, 2014								
Ch01 Mouse IS95 High	51.2 to 51.2	10.00	10.00	0.11/0.03	8.426	11.320	12549/12549	1.000
Ch02 Mouse IS95 Med	51.3 to 51.3	5.00	4.99	0.12/0.03	4.148	5.780	12549/12549	1.000
Ch03 Mouse IS95 Low	50.6 to 50.6	2.50	2.53	0.65/0.16	0.633	4.854	12390/12549	0.987
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	12532/12532	1.000
June 18, 2012, to July 9, 2014								
Ch01 Mouse IS95 High	18.9 to 54.1	10.95	9.97	0.17/0.04	0.124	21.444	1136122/ 1136284	1.000
Ch02 Mouse IS95 Med	18.9 to 54.9	5.00	4.99	0.15/0.03	0.771	12.768	1136228/ 1136284	1.000
Ch03 Mouse IS95 Low	18.9 to 54.7	2.50	2.49	0.21/0.05	0.161	6.319	1136030/ 1136283	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	0.00	–/0.00	0.000	0.000	1136208/ 1136208	1.000

[a]Ch = chamber (e.g., Ch11 = Chamber 11).

Table I-6. Summary of CDMA-modulated Cell Phone RFR Exposure Data—Chamber Field[a]

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
June 18 to 30, 2012							
Ch01 Mouse IS95 High	194.10 to 199.60	196.37	0.13/2.96	143.58	277.18	38944/38950	1.000
Ch02 Mouse IS95 Med	137.20 to 141.20	138.19	0.17/2.76	120.44	170.46	38950/38950	1.000
Ch03 Mouse IS95 Low	97.00 to 99.80	98.08	0.12/1.31	91.19	110.93	38950/38950	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	38950/38950	1.000
July 1 to 31, 2012							
Ch01 Mouse IS95 High	199.60 to 212.30	205.11	0.12/2.82	173.76	270.15	97460/97462	1.000
Ch02 Mouse IS95 Med	141.20 to 150.10	145.03	0.15/2.59	125.14	196.92	97460/97462	1.000
Ch03 Mouse IS95 Low	99.80 to 106.10	103.17	0.11/1.37	88.58	137.22	97460/97462	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97462/97462	1.000
August 1 to 31, 2012							
Ch01 Mouse IS95 High	212.30 to 222.20	217.26	0.12/2.98	199.87	258.23	94976/94976	1.000
Ch02 Mouse IS95 Med	150.10 to 157.10	152.68	0.15/2.58	138.34	208.61	94974/94976	1.000
Ch03 Mouse IS95 Low	106.10 to 111.10	108.44	0.11/1.37	98.59	132.85	94976/94976	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94976/94976	1.000
September 1 to 30, 2012							
Ch01 Mouse IS95 High	222.20 to 230.90	227.67	0.11/2.97	212.83	244.74	94374/94374	1.000
Ch02 Mouse IS95 Med	157.10 to 161.40	159.33	0.13/2.37	148.22	184.17	94374/94374	1.000
Ch03 Mouse IS95 Low	111.10 to 114.10	112.90	0.11/1.46	104.64	121.19	94374/94374	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94370/94370	1.000
October 1 to 31, 2012							
Ch01 Mouse IS95 High	230.90 to 237.60	233.91	0.11/3.07	215.34	250.45	97604/97604	1.000
Ch02 Mouse IS95 Med	161.40 to 166.60	163.67	0.13/2.46	151.48	176.83	97604/97604	1.000
Ch03 Mouse IS95 Low	114.10 to 117.80	115.72	0.11/1.42	108.66	123.97	97604/97604	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97602/97602	1.000
November 1 to 30, 2012							
Ch01 Mouse IS95 High	237.60 to 242.70	240.37	0.11/3.13	158.92	257.10	94626/94628	1.000
Ch02 Mouse IS95 Med	166.60 to 171.70	169.18	0.13/2.58	116.96	185.43	94626/94628	1.000
Ch03 Mouse IS95 Low	117.80 to 120.60	119.29	0.12/1.60	80.77	131.35	94626/94628	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94628/94628	1.000
December 1 to 31, 2012							
Ch01 Mouse IS95 High	242.70 to 247.20	245.58	0.11/3.21	231.33	264.34	97500/97500	1.000
Ch02 Mouse IS95 Med	171.70 to 173.80	172.59	0.13/2.64	162.14	190.41	97500/97500	1.000
Ch03 Mouse IS95 Low	120.60 to 122.90	121.97	0.11/1.55	113.87	132.39	97500/97500	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97496/97496	1.000
January 1 to 31, 2013							
Ch01 Mouse IS95 High	247.20 to 249.80	249.07	0.12/3.50	230.99	272.55	97378/97378	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch02 Mouse IS95 Med	173.80 to 175.70	174.88	0.13/2.63	161.36	189.41	97378/97378	1.000
Ch03 Mouse IS95 Low	122.90 to 124.30	123.76	0.11/1.65	115.26	135.11	97378/97378	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97364/97364	1.000
February 1 to 28, 2013							
Ch01 Mouse IS95 High	249.80 to 252.40	251.73	0.12/3.39	233.92	274.28	88116/88116	1.000
Ch02 Mouse IS95 Med	175.70 to 177.60	176.86	0.14/2.85	156.42	211.68	88116/88116	1.000
Ch03 Mouse IS95 Low	124.30 to 125.60	125.26	0.12/1.67	115.38	138.19	88116/88116	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	88116/88116	1.000
March 1 to 31, 2013							
Ch01 Mouse IS95 High	252.40 to 253.60	253.18	0.12/3.50	236.57	269.59	97784/97784	1.000
Ch02 Mouse IS95 Med	177.60 to 179.30	178.79	0.14/2.88	165.47	199.50	97784/97784	1.000
Ch03 Mouse IS95 Low	125.60 to 126.20	125.98	0.11/1.61	118.72	133.49	97784/97784	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97784/97784	1.000
April 1 to 30, 2013							
Ch01 Mouse IS95 High	253.60 to 257.20	255.59	0.12/3.58	235.87	288.37	96260/96260	1.000
Ch02 Mouse IS95 Med	179.30 to 181.80	179.86	0.14/2.87	167.66	195.71	96260/96260	1.000
Ch03 Mouse IS95 Low	126.20 to 128.60	127.23	0.12/1.72	119.08	136.24	96260/96260	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	96260/96260	1.000
May 1 to 31, 2013							
Ch01 Mouse IS95 High	257.20 to 259.40	257.37	0.14/4.29	226.87	285.93	97020/97020	1.000
Ch02 Mouse IS95 Med	181.80 to 183.40	181.64	0.14/2.98	167.27	205.30	97020/97020	1.000
Ch03 Mouse IS95 Low	128.60 to 129.10	128.55	0.12/1.77	119.88	141.09	97020/97020	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97020/97020	1.000
June 1 to 30, 2013							
Ch01 Mouse IS95 High	259.40 to 260.60	259.64	0.15/4.39	227.53	294.63	94514/94514	1.000
Ch02 Mouse IS95 Med	183.40 to 184.20	183.31	0.14/3.05	164.59	201.45	94514/94514	1.000
Ch03 Mouse IS95 Low	129.10 to 130.30	129.22	0.25/3.81	98.48	159.44	94506/94514	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94496/94496	1.000
July 1 to 31, 2013							
Ch01 Mouse IS95 High	260.60 to 261.60	260.92	0.16/4.87	230.46	304.39	99146/99146	1.000
Ch02 Mouse IS95 Med	184.20 to 185.00	184.01	0.14/3.03	168.19	202.70	99146/99146	1.000
Ch03 Mouse IS95 Low	130.30 to 130.80	130.53	0.28/4.24	105.17	158.30	99146/99146	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	99146/99146	1.000
August 1 to 31, 2013							
Ch01 Mouse IS95 High	261.60 to 262.80	261.92	0.14/4.30	222.33	288.89	101712/101712	1.000
Ch02 Mouse IS95 Med	185.00 to 185.80	185.08	0.16/3.35	171.22	210.82	101712/101712	1.000
Ch03 Mouse IS95 Low	130.80 to 131.40	130.89	0.14/2.08	113.00	145.03	101712/101712	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	101700/101700	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
September 1 to 30, 2013							
Ch01 Mouse IS95 High	262.80 to 275.00	264.04	0.14/4.41	235.55	309.86	93922/93922	1.000
Ch02 Mouse IS95 Med	185.80 to 186.60	186.05	0.15/3.20	169.04	209.04	93922/93922	1.000
Ch03 Mouse IS95 Low	131.40 to 131.90	131.72	0.35/5.41	93.28	169.36	93890/93922	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	93920/93920	1.000
October 1 to 31, 2013							
Ch01 Mouse IS95 High	262.80 to 263.90	263.44	0.13/4.00	236.10	288.79	100816/100816	1.000
Ch02 Mouse IS95 Med	186.60 to 187.40	186.81	0.15/3.17	171.27	216.71	100816/100816	1.000
Ch03 Mouse IS95 Low	131.90 to 132.50	132.12	0.17/2.54	109.99	152.72	100816/100816	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	100816/100816	1.000
November 1 to 30, 2013							
Ch01 Mouse IS95 High	263.90 to 263.90	263.87	0.15/4.69	177.48	291.88	93274/93278	1.000
Ch02 Mouse IS95 Med	187.40 to 187.40	187.21	0.16/3.50	125.18	208.73	93274/93278	1.000
Ch03 Mouse IS95 Low	131.90 to 132.50	131.56	0.33/5.16	33.46	176.17	93098/93278	0.998
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	93226/93226	1.000
December 1 to 31, 2013							
Ch01 Mouse IS95 High	262.80 to 263.90	263.08	0.14/4.35	221.94	318.53	96846/96846	1.000
Ch02 Mouse IS95 Med	185.80 to 187.40	186.01	0.16/3.57	166.56	220.78	96846/96846	1.000
Ch03 Mouse IS95 Low	131.40 to 131.90	131.34	0.14/2.10	117.52	144.93	96846/96846	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	96846/96846	1.000
January 1 to 31, 2014							
Ch01 Mouse IS95 High	262.80 to 262.80	262.41	0.14/4.18	205.46	313.40	97552/97554	1.000
Ch02 Mouse IS95 Med	185.80 to 186.60	186.14	0.16/3.37	97.83	212.15	97550/97554	1.000
Ch03 Mouse IS95 Low	131.40 to 131.40	131.41	0.31/4.82	54.39	168.36	97536/97552	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97550/97550	1.000
February 1 to 28, 2014							
Ch01 Mouse IS95 High	262.80 to 265.00	264.44	0.13/4.06	212.35	308.55	88184/88184	1.000
Ch02 Mouse IS95 Med	186.60 to 187.40	187.06	0.16/3.50	127.99	263.90	88170/88184	1.000
Ch03 Mouse IS95 Low	131.40 to 132.50	131.92	0.36/5.64	97.78	163.25	88120/88184	0.999
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	88184/88184	1.000
March 1 to 31, 2014							
Ch01 Mouse IS95 High	262.80 to 265.00	255.18	0.64/19.48	22.44	353.11	96940/97180	0.998
Ch02 Mouse IS95 Med	186.60 to 187.40	187.10	0.16/3.42	122.08	258.06	97170/97180	1.000
Ch03 Mouse IS95 Low	132.50 to 132.50	131.79	0.38/5.91	65.38	210.94	97010/97180	0.998
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97142/97142	1.000
April 1 to 30, 2014							
Ch01 Mouse IS95 High	261.60 to 262.80	261.90	0.27/8.39	22.44	384.56	94478/94550	0.999
Ch02 Mouse IS95 Med	185.80 to 186.60	186.68	0.20/4.33	73.16	297.77	94476/94550	0.999

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch03 Mouse IS95 Low	131.90 to 131.90	131.23	0.28/4.23	67.49	155.79	94522/94550	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94548/94548	1.000
May 1 to 31, 2014							
Ch01 Mouse IS95 High	260.60 to 261.60	261.26	0.14/4.17	236.40	291.11	97244/97244	1.000
Ch02 Mouse IS95 Med	185.00 to 185.80	185.64	0.14/2.95	159.77	212.41	97244/97244	1.000
Ch03 Mouse IS95 Low	131.40 to 131.90	131.27	0.28/4.25	94.32	156.82	97238/97244	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	97244/97244	1.000
June 1 to 30, 2014							
Ch01 Mouse IS95 High	260.60 to 261.60	260.64	0.13/3.91	219.82	287.61	94288/94288	1.000
Ch02 Mouse IS95 Med	184.20 to 185.00	184.79	0.14/2.97	153.76	204.42	94288/94288	1.000
Ch03 Mouse IS95 Low	130.30 to 131.40	130.58	0.28/4.32	84.05	165.61	94264/94288	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	94288/94288	1.000
July 1 to 9, 2014							
Ch01 Mouse IS95 High	261.60 to 261.60	261.65	0.11/3.45	240.24	278.45	25098/25098	1.000
Ch02 Mouse IS95 Med	185.00 to 185.00	184.91	0.12/2.53	168.56	198.96	25098/25098	1.000
Ch03 Mouse IS95 Low	130.30 to 130.30	130.67	0.68/10.57	65.61	181.71	24784/25098	0.987
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	25064/25064	1.000
June 18, 2012, to July 9, 2014							
Ch01 Mouse IS95 High	194.10 to 275.00	250.68	0.20/5.84	22.44	384.56	2272240/2272568	1.000
Ch02 Mouse IS95 Med	137.20 to 187.40	177.23	0.15/3.06	73.16	297.77	2272456/2272568	1.000
Ch03 Mouse IS95 Low	97.00 to 132.50	125.25	0.22/3.20	33.46	210.94	2272056/2272566	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.00	–/0.00	0.00	0.00	2272416/2272416	1.000

[a]Ch = chamber (e.g., Ch11 = Chamber 11).

Table I-7. Summary of CDMA-modulated Cell Phone RFR Exposure Data—E-Field[a]

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
June 18 to 30, 2012							
Ch01 Mouse IS95 High	194.1 to 199.6	182.96	0.16/3.46	132.6	264.8	38944/38950	1.000
Ch02 Mouse IS95 Med	137.2 to 141.2	127.98	0.20/2.95	109.8	152.6	38926/38950	0.999
Ch03 Mouse IS95 Low	97.0 to 99.8	94.73	0.17/1.82	86.4	108.0	38950/38950	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	38950/38950	1.000
July 1 to 31, 2012							
Ch01 Mouse IS95 High	199.6 to 212.3	191.13	0.18/3.93	161.2	251.6	97458/97462	1.000
Ch02 Mouse IS95 Med	141.2 to 150.1	134.04	0.20/3.16	115.7	186.0	97458/97462	1.000
Ch03 Mouse IS95 Low	99.8 to 106.1	99.09	0.17/1.98	83.9	131.8	97460/97462	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97462/97462	1.000
August 1 to 31, 2012							
Ch01 Mouse IS95 High	212.3 to 222.2	204.21	0.16/3.81	186.0	241.5	94976/94976	1.000
Ch02 Mouse IS95 Med	150.1 to 157.1	140.96	0.20/3.34	124.8	194.4	94974/94976	1.000
Ch03 Mouse IS95 Low	106.1 to 111.1	104.20	0.18/2.18	94.2	127.8	94976/94976	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94976/94976	1.000
September 1 to 30, 2012							
Ch01 Mouse IS95 High	222.2 to 230.9	214.97	0.17/4.21	191.7	239.8	94374/94374	1.000
Ch02 Mouse IS95 Med	157.1 to 161.4	147.53	0.18/3.03	133.9	170.0	94374/94374	1.000
Ch03 Mouse IS95 Low	111.1 to 114.1	107.71	0.17/2.09	98.9	118.0	94374/94374	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94370/94370	1.000
October 1 to 31, 2012							
Ch01 Mouse IS95 High	230.9 to 237.6	221.21	0.15/3.87	201.8	239.3	97604/97604	1.000
Ch02 Mouse IS95 Med	161.4 to 166.6	149.17	0.17/2.99	134.5	163.2	97604/97604	1.000
Ch03 Mouse IS95 Low	114.1 to 117.8	112.30	0.17/2.27	101.0	125.3	97604/97604	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97602/97602	1.000
November 1 to 30, 2012							
Ch01 Mouse IS95 High	237.6 to 242.7	227.51	0.17/4.54	151.4	254.3	94626/94628	1.000
Ch02 Mouse IS95 Med	166.6 to 171.7	154.82	0.18/3.32	104.7	176.2	94626/94628	1.000
Ch03 Mouse IS95 Low	117.8 to 120.6	116.59	0.17/2.36	76.7	128.5	94626/94628	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94628/94628	1.000
December 1 to 31, 2012							
Ch01 Mouse IS95 High	242.7 to 247.2	233.09	0.17/4.48	213.6	253.7	97500/97500	1.000
Ch02 Mouse IS95 Med	171.7 to 173.8	159.76	0.19/3.47	144.1	176.0	97500/97500	1.000
Ch03 Mouse IS95 Low	120.6 to 122.9	118.37	0.19/2.59	109.0	131.2	97500/97500	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97496/97496	1.000
January 1 to 31, 2013							
Ch01 Mouse IS95 High	247.2 to 249.8	235.20	0.16/4.42	215.1	260.4	97378/97378	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch02 Mouse IS95 Med	173.8 to 175.7	162.37	0.18/3.35	148.0	178.4	97378/97378	1.000
Ch03 Mouse IS95 Low	122.9 to 124.3	118.71	0.18/2.51	108.3	130.2	97378/97378	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97364/97364	1.000
February 1 to 28, 2013							
Ch01 Mouse IS95 High	249.8 to 252.4	238.62	0.16/4.53	217.4	264.4	88116/88116	1.000
Ch02 Mouse IS95 Med	175.7 to 177.6	162.29	0.19/3.61	141.3	193.5	88116/88116	1.000
Ch03 Mouse IS95 Low	124.3 to 125.6	119.75	0.19/2.59	109.5	131.5	88116/88116	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	88116/88116	1.000
March 1 to 31, 2013							
Ch01 Mouse IS95 High	252.4 to 253.6	238.57	0.18/5.13	219.6	265.7	97784/97784	1.000
Ch02 Mouse IS95 Med	177.6 to 179.3	164.78	0.19/3.74	149.7	187.8	97784/97784	1.000
Ch03 Mouse IS95 Low	125.6 to 126.2	122.27	0.20/2.80	111.3	136.0	97784/97784	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97784/97784	1.000
April 1 to 30, 2013							
Ch01 Mouse IS95 High	253.6 to 257.2	242.43	0.19/5.50	219.5	273.9	96260/96260	1.000
Ch02 Mouse IS95 Med	179.3 to 181.8	167.11	0.18/3.58	151.5	185.2	96260/96260	1.000
Ch03 Mouse IS95 Low	126.2 to 128.6	123.32	0.18/2.59	113.4	135.4	96260/96260	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	96260/96260	1.000
May 1 to 31, 2013							
Ch01 Mouse IS95 High	257.2 to 259.4	244.96	0.20/5.75	215.4	275.7	97020/97020	1.000
Ch02 Mouse IS95 Med	181.8 to 183.4	168.02	0.18/3.60	150.5	190.8	97020/97020	1.000
Ch03 Mouse IS95 Low	128.6 to 129.1	124.68	0.18/2.57	113.0	137.8	97020/97020	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97020/97020	1.000
June 1 to 30, 2013							
Ch01 Mouse IS95 High	259.4 to 260.6	246.98	0.21/5.93	212.0	288.6	94514/94514	1.000
Ch02 Mouse IS95 Med	183.4 to 184.2	170.19	0.18/3.64	154.4	190.5	94514/94514	1.000
Ch03 Mouse IS95 Low	129.1 to 130.3	128.47	0.64/9.79	88.7	176.8	94186/94514	0.997
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94496/94496	1.000
July 1 to 31, 2013							
Ch01 Mouse IS95 High	260.6 to 261.6	249.22	0.21/6.06	220.7	300.9	99146/99146	1.000
Ch02 Mouse IS95 Med	184.2 to 185.0	170.91	0.19/3.80	154.7	193.1	99146/99146	1.000
Ch03 Mouse IS95 Low	130.3 to 130.8	141.91	0.62/10.43	96.1	177.5	98928/99146	0.998
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	99146/99146	1.000
August 1 to 31, 2013							
Ch01 Mouse IS95 High	261.6 to 262.8	249.57	0.20/5.69	215.3	288.2	101712/101712	1.000
Ch02 Mouse IS95 Med	185.0 to 185.8	170.62	0.20/3.99	153.4	196.1	101712/101712	1.000
Ch03 Mouse IS95 Low	130.8 to 131.4	147.36	0.24/4.17	111.4	161.5	101712/101712	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	101700/101700	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
September 1 to 30, 2013							
Ch01 Mouse IS95 High	262.8 to 275.0	254.31	0.20/6.01	220.4	300.7	93922/93922	1.000
Ch02 Mouse IS95 Med	185.8 to 186.6	171.99	0.19/3.87	155.0	194.2	93922/93922	1.000
Ch03 Mouse IS95 Low	131.4 to 131.9	136.81	0.82/13.59	85.5	183.6	93028/93922	0.990
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	93920/93920	1.000
October 1 to 31, 2013							
Ch01 Mouse IS95 High	262.8 to 263.9	250.46	0.20/5.73	221.9	282.9	100816/100816	1.000
Ch02 Mouse IS95 Med	186.6 to 187.4	172.10	0.19/3.78	158.0	197.8	100816/100816	1.000
Ch03 Mouse IS95 Low	131.9 to 132.5	140.01	0.32/5.24	95.8	158.3	100766/100816	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	100816/100816	1.000
November 1 to 30, 2013							
Ch01 Mouse IS95 High	263.9 to 263.9	254.87	0.21/6.33	172.3	287.3	93272/93278	1.000
Ch02 Mouse IS95 Med	187.4 to 187.4	173.77	0.22/4.48	116.2	196.2	93242/93278	1.000
Ch03 Mouse IS95 Low	131.9 to 132.5	139.81	0.43/7.11	34.8	193.8	92976/93278	0.997
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	93226/93226	1.000
December 1 to 31, 2013							
Ch01 Mouse IS95 High	262.8 to 263.9	264.86	0.26/8.09	222.6	327.2	96846/96846	1.000
Ch02 Mouse IS95 Med	185.8 to 187.4	174.60	0.22/4.51	152.2	209.3	96846/96846	1.000
Ch03 Mouse IS95 Low	131.4 to 131.9	141.81	0.23/3.79	119.4	161.0	96846/96846	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	96846/96846	1.000
January 1 to 31, 2014							
Ch01 Mouse IS95 High	262.8 to 262.8	259.88	0.24/7.35	197.0	322.5	97552/97554	1.000
Ch02 Mouse IS95 Med	185.8 to 186.6	171.64	0.20/4.08	93.5	198.8	97550/97554	1.000
Ch03 Mouse IS95 Low	131.4 to 131.4	138.63	0.57/9.33	56.5	182.3	96868/97552	0.993
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97550/97550	1.000
February 1 to 28, 2014							
Ch01 Mouse IS95 High	262.8 to 265.0	254.65	0.22/6.40	202.8	293.6	88182/88184	1.000
Ch02 Mouse IS95 Med	186.6 to 187.4	172.87	0.22/4.50	121.5	251.8	88162/88184	1.000
Ch03 Mouse IS95 Low	131.4 to 132.5	130.86	0.88/13.88	85.2	176.6	87104/88184	0.988
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	88184/88184	1.000
March 1 to 31, 2014							
Ch01 Mouse IS95 High	262.8 to 265.0	248.73	0.66/19.55	21.5	370.2	96900/97180	0.997
Ch02 Mouse IS95 Med	186.6 to 187.4	178.11	0.21/4.32	114.7	249.5	97168/97180	1.000
Ch03 Mouse IS95 Low	132.5 to 132.5	125.83	0.60/8.93	56.2	202.2	96866/97180	0.997
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97142/97142	1.000
April 1 to 30, 2014							
Ch01 Mouse IS95 High	261.6 to 262.8	251.78	0.30/8.89	20.9	380.7	94432/94550	0.999
Ch02 Mouse IS95 Med	185.8 to 186.6	176.58	0.25/5.24	68.9	283.3	94536/94550	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch03 Mouse IS95 Low	131.9 to 131.9	132.52	0.51/7.96	68.5	160.3	94454/94550	0.999
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94548/94548	1.000
May 1 to 31, 2014							
Ch01 Mouse IS95 High	260.6 to 261.6	250.61	0.21/6.02	218.6	280.8	97244/97244	1.000
Ch02 Mouse IS95 Med	185.0 to 185.8	174.90	0.18/3.74	145.3	200.0	97242/97244	1.000
Ch03 Mouse IS95 Low	131.4 to 131.9	129.23	0.53/8.16	89.0	165.6	97218/97244	1.000
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	97244/97244	1.000
June 1 to 30, 2014							
Ch01 Mouse IS95 High	260.6 to 261.6	253.68	0.18/5.36	213.1	282.1	94288/94288	1.000
Ch02 Mouse IS95 Med	184.2 to 185.0	177.67	0.23/4.76	153.6	200.6	94288/94288	1.000
Ch03 Mouse IS95 Low	130.3 to 131.4	125.07	0.47/6.93	79.5	174.0	94236/94288	0.999
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	94288/94288	1.000
July 1 to 9, 2014							
Ch01 Mouse IS95 High	261.6 to 261.6	259.20	0.16/4.71	236.0	277.7	25098/25098	1.000
Ch02 Mouse IS95 Med	185.0 to 185.0	184.69	0.16/3.33	168.3	199.6	25098/25098	1.000
Ch03 Mouse IS95 Low	130.3 to 130.3	127.53	0.87/13.46	60.8	192.7	24686/25098	0.984
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	25064/25064	1.000
June 18, 2012, to July 9, 2014							
Ch01 Mouse IS95 High	194.1 to 275.0	239.79	0.28/7.76	20.9	380.7	2272148/ 2272568	1.000
Ch02 Mouse IS95 Med	137.2 to 187.4	164.41	0.22/4.14	68.9	283.3	2272446/ 2272568	1.000
Ch03 Mouse IS95 Low	97.0 to 132.5	125.83	0.60/9.02	34.8	202.2	2268550/ 2272566	0.998
Ch13 Mouse Sham	0.0 to 0.0	0.00	–/0.00	0.0	0.0	2272416/ 2272416	1.000

[a]Ch = chamber (e.g., Ch11 = Chamber 11).

Table I-8. Summary of CDMA-modulated Cell Phone RFR Exposure Data—H-Field[a]

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
June 18 to 30, 2012							
Ch01 Mouse IS95 High	0.52 to 0.53	0.556	0.17/0.011	0.41	0.77	38948/38950	1.000
Ch02 Mouse IS95 Med	0.36 to 0.38	0.394	0.22/0.010	0.35	0.50	38948/38950	1.000
Ch03 Mouse IS95 Low	0.26 to 0.27	0.269	0.17/0.005	0.25	0.30	38950/38950	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	38950/38950	1.000
July 1 to 31, 2012							
Ch01 Mouse IS95 High	0.53 to 0.56	0.581	0.19/0.013	0.49	0.77	97460/97462	1.000
Ch02 Mouse IS95 Med	0.38 to 0.40	0.414	0.21/0.010	0.36	0.55	97460/97462	1.000
Ch03 Mouse IS95 Low	0.27 to 0.28	0.284	0.17/0.005	0.25	0.38	97460/97462	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97462/97462	1.000
August 1 to 31, 2012							
Ch01 Mouse IS95 High	0.56 to 0.59	0.611	0.17/0.012	0.55	0.73	94976/94976	1.000
Ch02 Mouse IS95 Med	0.40 to 0.42	0.436	0.21/0.011	0.39	0.59	94974/94976	1.000
Ch03 Mouse IS95 Low	0.28 to 0.30	0.299	0.17/0.006	0.27	0.37	94974/94976	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94976/94976	1.000
September 1 to 30, 2012							
Ch01 Mouse IS95 High	0.59 to 0.61	0.638	0.17/0.013	0.58	0.69	94374/94374	1.000
Ch02 Mouse IS95 Med	0.42 to 0.43	0.454	0.19/0.010	0.42	0.53	94374/94374	1.000
Ch03 Mouse IS95 Low	0.30 to 0.30	0.313	0.17/0.006	0.29	0.35	94374/94374	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94370/94370	1.000
October 1 to 31, 2012							
Ch01 Mouse IS95 High	0.61 to 0.63	0.654	0.16/0.012	0.59	0.70	97604/97604	1.000
Ch02 Mouse IS95 Med	0.43 to 0.44	0.473	0.19/0.010	0.43	0.51	97604/97604	1.000
Ch03 Mouse IS95 Low	0.30 to 0.31	0.316	0.17/0.006	0.29	0.34	97604/97604	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97602/97602	1.000
November 1 to 30, 2012							
Ch01 Mouse IS95 High	0.63 to 0.64	0.672	0.17/0.013	0.44	0.72	94626/94628	1.000
Ch02 Mouse IS95 Med	0.44 to 0.46	0.487	0.22/0.012	0.34	0.54	94626/94628	1.000
Ch03 Mouse IS95 Low	0.31 to 0.32	0.324	0.17/0.006	0.23	0.36	94626/94628	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94628/94628	1.000
December 1 to 31, 2012							
Ch01 Mouse IS95 High	0.64 to 0.66	0.685	0.17/0.013	0.62	0.74	97500/97500	1.000
Ch02 Mouse IS95 Med	0.46 to 0.46	0.492	0.20/0.012	0.45	0.54	97500/97500	1.000
Ch03 Mouse IS95 Low	0.32 to 0.33	0.333	0.18/0.007	0.30	0.36	97500/97500	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97496/97496	1.000
January 1 to 31, 2013							
Ch01 Mouse IS95 High	0.66 to 0.66	0.697	0.17/0.014	0.63	0.77	97378/97378	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch02 Mouse IS95 Med	0.46 to 0.47	0.497	0.19/0.011	0.45	0.55	97378/97378	1.000
Ch03 Mouse IS95 Low	0.33 to 0.33	0.342	0.18/0.007	0.31	0.38	97378/97378	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97364/97364	1.000
February 1 to 28, 2013							
Ch01 Mouse IS95 High	0.66 to 0.67	0.702	0.16/0.013	0.65	0.77	88116/88116	1.000
Ch02 Mouse IS95 Med	0.47 to 0.47	0.508	0.21/0.012	0.46	0.61	88114/88116	1.000
Ch03 Mouse IS95 Low	0.33 to 0.33	0.347	0.18/0.007	0.32	0.38	88116/88116	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	88116/88116	1.000
March 1 to 31, 2013							
Ch01 Mouse IS95 High	0.67 to 0.67	0.710	0.19/0.015	0.65	0.77	97784/97784	1.000
Ch02 Mouse IS95 Med	0.47 to 0.48	0.511	0.22/0.013	0.46	0.56	97784/97784	1.000
Ch03 Mouse IS95 Low	0.33 to 0.34	0.344	0.19/0.008	0.32	0.38	97784/97784	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97784/97784	1.000
April 1 to 30, 2013							
Ch01 Mouse IS95 High	0.67 to 0.68	0.713	0.20/0.016	0.65	0.82	96260/96260	1.000
Ch02 Mouse IS95 Med	0.48 to 0.48	0.511	0.19/0.011	0.47	0.56	96260/96260	1.000
Ch03 Mouse IS95 Low	0.34 to 0.34	0.348	0.18/0.007	0.32	0.38	96260/96260	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	96260/96260	1.000
May 1 to 31, 2013							
Ch01 Mouse IS95 High	0.68 to 0.69	0.716	0.19/0.016	0.63	0.79	97020/97020	1.000
Ch02 Mouse IS95 Med	0.48 to 0.49	0.518	0.21/0.013	0.46	0.59	97020/97020	1.000
Ch03 Mouse IS95 Low	0.34 to 0.34	0.351	0.17/0.007	0.32	0.39	97020/97020	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97020/97020	1.000
June 1 to 30, 2013							
Ch01 Mouse IS95 High	0.69 to 0.69	0.722	0.20/0.017	0.64	0.84	94514/94514	1.000
Ch02 Mouse IS95 Med	0.49 to 0.49	0.521	0.21/0.013	0.46	0.57	94514/94514	1.000
Ch03 Mouse IS95 Low	0.34 to 0.35	0.345	0.53/0.022	0.28	0.43	94512/94514	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94496/94496	1.000
July 1 to 31, 2013							
Ch01 Mouse IS95 High	0.69 to 0.69	0.723	0.21/0.018	0.63	0.84	99146/99146	1.000
Ch02 Mouse IS95 Med	0.49 to 0.49	0.523	0.21/0.013	0.48	0.58	99146/99146	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.316	0.45/0.017	0.28	0.41	99146/99146	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	99146/99146	1.000
August 1 to 31, 2013							
Ch01 Mouse IS95 High	0.69 to 0.70	0.727	0.19/0.016	0.60	0.81	101712/101712	1.000
Ch02 Mouse IS95 Med	0.49 to 0.49	0.529	0.22/0.013	0.48	0.62	101710/101712	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.303	0.18/0.006	0.28	0.35	101712/101712	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	101700/101700	1.000

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
September 1 to 30, 2013							
Ch01 Mouse IS95 High	0.70 to 0.73	0.726	0.19/0.016	0.63	0.85	93922/93922	1.000
Ch02 Mouse IS95 Med	0.49 to 0.50	0.531	0.22/0.013	0.47	0.59	93922/93922	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.336	0.62/0.025	0.22	0.45	93914/93922	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	93920/93920	1.000
October 1 to 31, 2013							
Ch01 Mouse IS95 High	0.70 to 0.70	0.733	0.19/0.016	0.66	0.82	100816/100816	1.000
Ch02 Mouse IS95 Med	0.50 to 0.50	0.535	0.22/0.013	0.49	0.63	100816/100816	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.330	0.22/0.008	0.29	0.41	100816/100816	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	100816/100816	1.000
November 1 to 30, 2013							
Ch01 Mouse IS95 High	0.70 to 0.70	0.724	0.20/0.017	0.48	0.81	93274/93278	1.000
Ch02 Mouse IS95 Med	0.50 to 0.50	0.532	0.23/0.014	0.36	0.59	93276/93278	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.327	0.27/0.010	0.19	0.43	93096/93278	0.998
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	93226/93226	1.000
December 1 to 31, 2013							
Ch01 Mouse IS95 High	0.70 to 0.70	0.693	0.25/0.020	0.59	0.82	96846/96846	1.000
Ch02 Mouse IS95 Med	0.49 to 0.50	0.524	0.24/0.015	0.46	0.62	96844/96846	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.321	0.19/0.007	0.28	0.36	96846/96846	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	96846/96846	1.000
January 1 to 31, 2014							
Ch01 Mouse IS95 High	0.70 to 0.70	0.703	0.22/0.018	0.57	0.81	97554/97554	1.000
Ch02 Mouse IS95 Med	0.49 to 0.50	0.532	0.22/0.014	0.27	0.62	97550/97554	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.329	0.39/0.015	0.14	0.41	97542/97552	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97550/97550	1.000
February 1 to 28, 2014							
Ch01 Mouse IS95 High	0.70 to 0.70	0.727	0.21/0.018	0.59	0.86	88184/88184	1.000
Ch02 Mouse IS95 Med	0.50 to 0.50	0.534	0.24/0.015	0.36	0.74	88170/88184	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.353	0.70/0.029	0.27	0.41	88180/88184	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	88184/88184	1.000
March 1 to 31, 2014							
Ch01 Mouse IS95 High	0.70 to 0.70	0.694	0.65/0.054	0.10	0.90	96954/97180	0.998
Ch02 Mouse IS95 Med	0.50 to 0.50	0.520	0.21/0.013	0.34	0.71	97170/97180	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.365	0.43/0.019	0.19	0.58	97036/97180	0.999
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97142/97142	1.000
April 1 to 30, 2014							
Ch01 Mouse IS95 High	0.69 to 0.70	0.722	0.31/0.026	0.15	1.03	94494/94550	0.999
Ch02 Mouse IS95 Med	0.49 to 0.50	0.522	0.28/0.017	0.21	0.83	94406/94550	0.998

Chamber	Target Range [V/m]	Mean [V/m]	Stdev [dB]/[V/m]	Min [V/m]	Max [V/m]	In Range/ Total	Ratio
Ch03 Mouse IS95 Low	0.35 to 0.35	0.345	0.38/0.015	0.18	0.42	94540/94550	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94548/94548	1.000
May 1 to 31, 2014							
Ch01 Mouse IS95 High	0.69 to 0.69	0.721	0.21/0.017	0.64	0.82	97244/97244	1.000
Ch02 Mouse IS95 Med	0.49 to 0.49	0.521	0.20/0.012	0.46	0.60	97244/97244	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.354	0.37/0.016	0.26	0.42	97240/97244	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	97244/97244	1.000
June 1 to 30, 2014							
Ch01 Mouse IS95 High	0.69 to 0.69	0.710	0.17/0.014	0.60	0.79	94288/94288	1.000
Ch02 Mouse IS95 Med	0.49 to 0.49	0.509	0.24/0.014	0.41	0.57	94288/94288	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.361	0.27/0.011	0.24	0.43	94276/94288	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	94288/94288	1.000
July 1 to 9, 2014							
Ch01 Mouse IS95 High	0.69 to 0.69	0.701	0.14/0.011	0.65	0.76	25098/25098	1.000
Ch02 Mouse IS95 Med	0.49 to 0.49	0.491	0.14/0.008	0.44	0.53	25098/25098	1.000
Ch03 Mouse IS95 Low	0.35 to 0.35	0.355	0.68/0.029	0.19	0.49	24740/25098	0.986
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	25064/25064	1.000
June 18, 2012, to July 9, 2014							
Ch01 Mouse IS95 High	0.52 to 0.73	0.694	0.29/0.023	0.10	1.03	2272276/ 2272568	1.000
Ch02 Mouse IS95 Med	0.36 to 0.50	0.504	0.23/0.013	0.21	0.83	2272380/ 2272568	1.000
Ch03 Mouse IS95 Low	0.26 to 0.35	0.331	0.53/0.021	0.14	0.58	2272194/ 2272566	1.000
Ch13 Mouse Sham	0.00 to 0.00	0.000	–/0.000	0.00	0.00	2272416/ 2272416	1.000

[a]Ch = chamber (e.g., Ch11 = Chamber 11).

Appendix J. Ingredients, Nutrient Composition, and Contaminant Levels in NTP-2000 Rat and Mouse Ration

Tables

Table J-1. Ingredients of NTP-2000 Rat and Mouse Ration J-2
Table J-2. Vitamins and Minerals in NTP-2000 Rat and Mouse Ration J-2
Table J-3. Nutrient Composition of NTP-2000 Rat and Mouse Ration J-3
Table J-4. Contaminant Levels in NTP-2000 Rat and Mouse Ration J-5

Table J-1. Ingredients of NTP-2000 Rat and Mouse Ration

Ingredients	Percent by Weight
Ground hard winter wheat	22.26
Ground #2 yellow shelled corn	22.18
Wheat middlings	15.0
Oat hulls	8.5
Alfalfa meal (dehydrated, 17% protein)	7.5
Purified cellulose	5.5
Soybean meal (49% protein)	5.0
Fish meal (60% protein)	4.0
Corn oil (without preservatives)	3.0
Soy oil (without preservatives)	3.0
Dried brewer's yeast	1.0
Calcium carbonate (USP)	0.9
Vitamin premix[a]	0.5
Mineral premix[b]	0.5
Calcium phosphate, dibasic (USP)	0.4
Sodium chloride	0.3
Choline chloride (70% choline)	0.26
Methionine	0.2

[a]Wheat middlings as carrier.
[b]Calcium carbonate as carrier.

Table J-2. Vitamins and Minerals in NTP-2000 Rat and Mouse Ration[a]

	Amount	Source
Vitamins		
A	4,000 IU	Stabilized vitamin A palmitate or acetate
D	1,000 IU	D-activated animal sterol
K	1.0 mg	Menadione sodium bisulfite complex
α-Tocopheryl acetate	100 IU	–
Niacin	23 mg	–
Folic acid	1.1 mg	–
d-Pantothenic acid	10 mg	*d*-Calcium pantothenate
Riboflavin	3.3 mg	–
Thiamine	4 mg	Thiamine mononitrate
B_{12}	52 µg	–
Pyridoxine	6.3 mg	Pyridoxine hydrochloride
Biotin	0.2 mg	*d*-Biotin
Minerals		
Magnesium	514 mg	Magnesium oxide
Iron	35 mg	Iron sulfate
Zinc	12 mg	Zinc oxide
Manganese	10 mg	Manganese oxide
Copper	2.0 mg	Copper sulfate
Iodine	0.2 mg	Calcium iodate
Chromium	0.2 mg	Chromium acetate

[a]Per kg of finished product.

Table J-3. Nutrient Composition of NTP-2000 Rat and Mouse Ration

Nutrient	Mean ± Standard Deviation	Range	Number of Samples
Protein (% by weight)	14.4 ± 0.38	13.9–15.1	17
Crude fat (% by weight)	8.4 ± 0.37	7.7–9.2	17
Crude fiber (% by weight)	9.4 ± 0.41	8.6–9.9	17
Ash (% by weight)	4.9 ± 0.13	4.7–5.1	17
Amino Acids (% of total diet)			
Arginine	0.794 ± 0.070	0.67–0.97	26
Cystine	0.220 ± 0.022	0.15–0.25	26
Glycine	0.700 ± 0.038	0.62–0.80	26
Histidine	0.344 ± 0.074	0.27–0.68	26
Isoleucine	0.546 ± 0.041	0.43–0.66	26
Leucine	1.092 ± 0.063	0.96–1.24	26
Lysine	0.700 ± 0.110	0.31–0.86	26
Methionine	0.408 ± 0.043	0.26–0.49	26
Phenylalanine	0.621 ± 0.048	0.47–0.72	26
Threonine	0.508 ± 0.040	0.43–0.61	26
Tryptophan	0.153 ± 0.027	0.11–0.20	26
Tyrosine	0.413 ± 0.063	0.28–0.54	26
Valine	0.663 ± 0.040	0.55–0.73	26
Essential Fatty Acids (% of total diet)			
Linoleic	3.95 ± 0.242	3.49–4.55	26
Linolenic	0.31 ± 0.030	0.21–0.35	26
Vitamins			
Vitamin A (IU/kg)	3,899 ± 77	2,820–5,450	17
Vitamin D (IU/kg)	1,000[a]		
α-Tocopherol (ppm)	79.7 ± 20.42	27.0–124.0	26
Thiamine (ppm)[b]	11.8 ± 17.85	6.6–81.0	17
Riboflavin (ppm)	8.1 ± 2.91	4.20–17.50	26
Niacin (ppm)	78.9 ± 8.52	66.4–98.2	26
Pantothenic acid (ppm)	26.7 ± 11.63	17.4–81.0	26
Pyridoxine (ppm)[b]	9.7 ± 2.09	6.44–14.3	26
Folic acid (ppm)	1.59 ± 0.45	1.15–3.27	26
Biotin (ppm)	0.32 ± 0.10	0.20–0.704	26
Vitamin B12 (ppb)	51.8 ± 36.6	18.3–174.0	26
Choline (ppm)[b]	2,665 ± 631	1,160–3,790	26

Nutrient	Mean ± Standard Deviation	Range	Number of Samples
Minerals			
Calcium (%)	0.903 ± 0.070	0.697–1.01	17
Phosphorus (%)	0.553 ± 0.026	0.510–0.596	17
Potassium (%)	0.669 ± 0.030	0.626–0.733	26
Chloride (%)	0.386 ± 0.037	0.300–0.474	26
Sodium (%)	0.193 ± 0.024	0.160–0.283	26
Magnesium (%)	0.216 ± 0.057	0.185–0.490	26
Sulfur (%)	0.170 ± 0.029	0.116–0.209	14
Iron (ppm)	190.5 ± 38.0	135–311	26
Manganese (ppm)	50.7 ± 9.72	21.0–73.1	26
Zinc (ppm)	58.2 ± 26.89	43.3–184.0	26
Copper (ppm)	7.44 ± 2.60	3.21–16.3	26
Iodine (ppm)	0.514 ± 0.195	0.158–0.972	26
Chromium (ppm)	0.674 ± 0.265	0.330–1.380	25
Cobalt (ppm)	0.235 ± 0.157	0.094–0.864	24

[a]From formulation.
[b]As hydrochloride (thiamine and pyridoxine) or chloride (choline).

Table J-4. Contaminant Levels in NTP-2000 Rat and Mouse Ration[a]

	Mean ± Standard Deviation[b]	Range	Number of Samples
Contaminants			
Arsenic (ppm)	0.20 ± 0.039	0.14–0.28	17
Cadmium (ppm)	0.05 ± 0.004	0.04–0.06	17
Lead (ppm)	0.21 ± 0.027	0.07–1.19	17
Mercury (ppm)	<0.02		17
Selenium (ppm)	0.17 ± 0.024	0.10–0.20	17
Aflatoxins (ppb)	<5.00		17
Nitrate nitrogen (ppm)[c]	18.76 ± 9.49	10.0–45.9	17
Nitrite nitrogen (ppm)[c]	0.61		17
BHA (ppm)[d]	<1.0		17
BHT (ppm)[d]	<1.0		17
Aerobic plate count (CFU/g)	<10.0		17
Coliform (MPN/g)	3.0		17
Escherichia coli (MPN/g)	<10		17
Salmonella (MPN/g)	Negative		17
Total nitrosoamines (ppb)[e]	9.2 ± 5.55	0.0–19.9	17
N-Nitrosodimethylamine (ppb)[e]	1.3 ± 1.04	0.0–3.0	17
N-Nitrosopyrrolidine (ppb)[e]	8.0 ± 5.02	0.0–18.6	17
Pesticides (ppm)			
α-BHC	<0.01	–	17
β-BHC	<0.02	–	17
γ-BHC	<0.01	–	17
δ-BHC	<0.01	–	17
Heptachlor	<0.01	–	17
Aldrin	<0.01	–	17
Heptachlor epoxide	<0.01	–	17
DDE	<0.01	–	17
DDD	<0.01	–	17
DDT	<0.01	–	17
HCB	<0.01	–	17
Mirex	<0.01	–	17
Methoxychlor	<0.05	–	17
Dieldrin	<0.01	–	17
Endrin	<0.01	–	17

	Mean ± Standard Deviation[b]	Range	Number of Samples
Telodrin	<0.01	–	17
Chlordane	<0.05	–	17
Toxaphene	<0.10	–	17
Estimated PCBs	<0.20	–	17
Ronnel	<0.01	–	17
Ethion	<0.02	–	17
Trithion	<0.05	–	17
Diazinon	<0.10	–	17
Methyl chlorpyrifos	0.16 ± 0.179	0.02–0.686	17
Methyl parathion	<0.02	–	17
Ethyl parathion	<0.02	–	17
Malathion	0.117 ± 0.140	0.02–0.585	17
Endosulfan I	<0.01	–	17
Endosulfan II	<0.01	–	17
Endosulfan sulfate	<0.03	–	17

[a]All samples were irradiated. CFU=colony-forming units; MPN=most probable number; BHC=hexachlorocyclohexane or benzene hexachloride.
[b]For values less than the limit of detection, the detection limit is given as the mean.
[c]Sources of contamination: alfalfa, grains, and fish meal.
[d]Sources of contamination: soy oil and fish meal.
[e]All values were corrected for percent recovery.

Appendix K. Sentinel Animal Program

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Table K-1. Laboratory Methods and Agents Tested for in the Sentinel Animal Program K-2

K.1. Methods

Rodents used in the National Toxicology Program are produced in optimally clean facilities to eliminate potential pathogens that may affect study results. The Sentinel Animal Program is part of the periodic monitoring of animal health that occurs during the toxicologic evaluation of test agents. Under this program, the disease state of the rodents is monitored via sera or feces from extra (sentinel) or dosed animals in the study rooms. The sentinel animals and the study animals are subject to identical environmental conditions. Furthermore, the sentinel animals come from the same production source and weanling groups as the animals used for the studies of test agents.

Blood samples were collected and allowed to clot, and the serum was separated. All samples were processed appropriately with serology testing performed by IDEXX BioResearch [formerly Research Animal Diagnostic Laboratory (RADIL), University of Missouri, Columbia, MO] for determination of the presence of pathogens. The laboratory methods and agents for which testing was performed are tabulated below; the times at which samples were collected during the studies are also listed.

Blood was collected from five mice per sex per time point except for the following:

- 28-day studies, study termination collection: Two males and eight females
- 2-year studies, study termination collection: 10 males and 10 females

Table K-1. Laboratory Methods and Agents Tested for in the Sentinel Animal Program

Method and Test	Time of Collection
28-day Studies	
Multiplex Fluorescent Immunoassay	
Ectromelia virus	Study termination
EDIM (epizootic diarrhea of infant mice)	Study termination
LCMV (lymphocytic choriomeningitis virus)	Study termination
Mycoplasma pulmonis	Study termination
MHV (mouse hepatitis virus)	Study termination
MNV (mouse norovirus)	Study termination
MPV (mouse parvovirus)	Study termination
MVM (minute virus of mice)	Study termination
PVM (pneumonia virus of mice)	Study termination
REO3 (reovirus)	Study termination
Sendai	Study termination
TMEV (Theiler's murine encephalomyelitis virus)	Study termination

Method and Test	Time of Collection
Two-Year Studies	
Multiplex Fluorescent Immunoassay	
Ectromelia virus	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
EDIM	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
LCMV	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
M. pulmonis	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
MHV	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
MNV	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
MPV	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
MVM	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
PVM	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
REO3	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
Sendai	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
TMEV	End of quarantine, 4 weeks, 6, 12, and 18 months, study termination
Immunofluorescence Assay	
MNV	Study termination
Polymerase Chain Reaction	
Helicobacter species	18 months

K.2. Results

All test results were negative.

Appendix L. Peer Reviews of the Draft NTP Technical Reports on Cell Phone Radiofrequency Radiation

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L.1. Introduction

The peer review of the Draft NTP Technical Reports on Cell Phone Radiofrequency Radiation was convened March 26 to 28, 2018 in Rodbell Auditorium, Rall Building, National Institute of Environmental Health Sciences (NIEHS), Research Triangle Park, North Carolina. Dr. David Eaton served as chair. Other peer-review panel members in attendance were Drs. Rick Adler, Lydia Andrews-Jones, Frank Barnes, J. Mark Cline, George Corcoran, Susan Felter, Jack Harkema, Wolfgang Kaufmann, Asimina Kiourti, James Lin, Tyler Malys, Matthias Rinke, and Laurence Whiteley, and Ms. Kamala Pant. Dr. Donald Stump attended as the NTP Board of Scientific Counselors liaison. Interested members of the public attended the meeting in person or watched the proceedings via webcast.

Dr. Eaton welcomed everyone to the meeting and asked all in-person attendees to introduce themselves. Dr. John Bucher welcomed participants, thanked the panel, and provided an orientation to the 3-day meeting. Designated Federal Official Dr. Mary Wolfe read the conflict of interest statement and asked panel members to sign updated conflict of interest forms. Dr. Eaton presented the meeting format, with Day 1 devoted to the technical aspects of the radiofrequency radiation (RFR) exposure facility, Day 2 addressing the mouse studies, and Day 3 covering the rat studies. Slide presentations for the meeting are available on the NTP website (https://ntp.niehs.nih.gov/go/ Presentations_RFR).

L.2. Attendees

Peer-Review Panel Chair
David Eaton, University of Washington

Peer-Review Panel 1
Provided consultation on the reverberation chamber exposure system
Frank Barnes, University of Colorado (retired)
Asimina Kiourti, The Ohio State University (present for Days 1 and 2)
James Lin, University of Illinois at Chicago

Peer-Review Panel 2
Provided input on study findings and voted on NTP's draft conclusions
Rick Adler, GlaxoSmithKline
Lydia Andrews-Jones, Allergan, Inc.
J. Mark Cline, Wake Forest School of Medicine
George Corcoran, Wayne State University
Susan Felter, Procter & Gamble
Jack Harkema, Michigan State University
Wolfgang Kaufmann, Merck (retired)
Tyler Malys, Data Management Services
Kamala Pant, BioReliance
Matthias Rinke, Bayer Pharma AG (retired)
Laurence Whiteley, Pfizer

Technical Experts
Myles Capstick, IT'IS Foundation
Niels Kuster, IT'IS Foundation
John Ladbury, National Institute of Standards and Technology

L.3. Panel 1: Peer Review of Exposure System for NTP Studies on Cell Phone RFR

Charge

Dr. Chad Blystone presented the Day 1 charge to the panel: to assess the reverberation chamber technology for evaluating the effects of cell phone RFR exposure in rats and mice.

Nomination, NTP's Considerations for Toxicological Evaluation of Radiofrequency Radiation Exposure in Rodents, and Background on Exposure System Selection

Dr. Michael Wyde described the NTP nomination of cell phone RFR exposure by the U.S. Food and Drug Administration (FDA) in 1999. The nomination was based on widespread and expanding human exposure, with little known about potential long-term health effects and insufficient data to assess risk to human health. The FDA and the Federal Communications Commission (FCC) share regulatory responsibility for RFR.

Dr. Wyde provided information about the background of the program, including establishment of research collaborations with RFR experts at the National Institute of Standards and Technology (NIST) and the IT'IS Foundation in Zurich, Switzerland. The IIT Research Institute (IITRI) in Chicago was chosen as the study laboratory. He discussed previous RFR toxicology studies and the selection of the exposure system for the NTP studies: frequencies of 900 MHz (rat) and 1,900 MHz (mouse) with both Global System for Mobile communications (GSM) and Code Division Multiple Access (CDMA) modulations, reflecting the standards in use when the study began. He described the reverberation chamber exposure system designed for the initiative.

Twenty-one reverberation chambers were constructed in Switzerland: seven each for mice, male rats, and female rats; male and female rats were separated due to weight differences between the sexes. For mice, male rats, and female rats, each group had separate low, medium, and high dosage chambers for the GSM and CDMA modulations, plus one common control chamber. Dosage for RFR is measured as specific absorption rate (SAR).

The toxicology and carcinogenicity studies, consisting of three phases, were conducted on B6C3F1/N mice and Hsd:Harlan Sprague Dawley rats.

- 5-day thermal pilot studies at SARs of 4 to 12 Watts/kilogram (W/kg) in young and aged mice and rats and pregnant rats (10 studies) – presented on Day 1
- 28-day prechronic toxicology studies – presented on Days 2 (mice) and 3 (rats)
- 2-year toxicology and carcinogenicity studies – presented on Days 2 (mice) and 3 (rats)

In all studies, daily exposure to RFR in the reverberation chambers totaled 9 hours, 10 minutes per day — 18 hours, 20 minutes per day in 10-minute on-off cycles. The system generating the signals ran continuously, alternating exposure to the GSM and CDMA groups.

Questions for Clarification

Dr. Harkema asked whether the study design had been flexible, given the project would be lengthy and inevitably the technology would change. Dr. Wyde said the program was locked into the technologies in use at the time, because switching during the course of the studies would have been very expensive.

Dr. Cline asked about the provenance of the cell phone usage information presented in Dr. Wyde's slides. Dr. Wyde said that most of the information had come from surveys. Dr. Cline also asked if the animals could perceive whether the machine was on or off and what kind of emissions were perceptible with the exposure. Dr. Wyde deferred this question for discussion during the toxicology portion of the studies.

Dr. Eaton asked about the involvement of light-cycle circadian rhythms in the exposure schedules, noting that mice and rats are nocturnal animals. Dr. Wyde described the two husbandry periods: one in the early morning and one in the afternoon. The exposures continued throughout the night, and circadian rhythms were not taken into account.

Dr. Lin asked about the presence of mechanical noise, particularly as related to stirrers or paddles. He asked if the stirrers were turned on in the control chambers. Dr. Wyde confirmed the stirrers were turned on in the control chambers. Dr. Lin asked about the sequence of the exposures. Dr. Wyde explained that the system that generated the signals alternated between GSM and CDMA, but all animals were exposed to only one of the modulations.

Dr. Barnes asked about the statistical variation of rodent exposure between the chambers. Dr. Wyde deferred the answer to Dr. Myles Capstick's talk.

Reverberation Chamber System for RFR Exposures

Dr. Capstick from the IT'IS Foundation briefed the panel on the physical and environmental design of the reverberation chambers. Requirements included:

- Ability to expose large numbers of rodents
- Ability to expose to a high SAR up to 20 hours per day
- Animals to be unconstrained and housed in standard laboratory cages
- Food and water to be available on demand
- Excellent field and SAR homogeneity
- Detailed dosimetry (numerical and experimental)
- Ability to discern a possible dose response
- Third-party verification of the correct operation of the system

Several elements were involved in the rationale for the selection of the exposure, including frequency, modulation, and extremely low frequency envelope. Dr. Capstick described the GSM and CDMA modulation methods. The reverberation chambers were described, including:

- Two mode stirrers per chamber to achieve high field homogeneity and isotropy (including stirrer speeds)

- Standard gain antennas
- Air flow system
- Chamber design
- Lighting (per specific NTP requirements)
- Chamber field uniformity
- Exposure field uncertainty
- Noise
- Air handling
- Drinking water provision/Automatic watering system
- Stirrers and sensors
- Control equipment and amplifiers
- Data acquisition

Details on aspects of the reverberation chamber listed above are included in Dr. Capstick's online presentation[m]. The constructed chambers were shipped from Switzerland to Chicago, where they were installed in a specially designed facility.

Questions for Clarification

Dr. Whiteley asked whether the animals were rotated in the caging. Dr. Capstick said that, as the animals moved around the cages, any inhomogeneity was evened out. The cages were rotated twice per week. Dr. Whiteley asked whether the 10 minutes on, 10 minutes off approach was used for a biological reason. Dr. Capstick said previous studies had shown the intermittency of exposure was an important factor biologically. Dr. Kuster elaborated on the prior studies.

Dr. Lin asked for more information regarding the exposure alternation. Dr. Capstick explained that, for 10 minutes, the energy was sent to the GSM chambers, and in the following 10 minutes, it was sent to the CDMA chambers. The chambers and their exposures were separate.

Dr. Lin noted that the historical data had been gathered in conditions using fluorescent lighting, as opposed to the incandescent lighting chosen for the NTP experiments. He considered the different lighting sources weakened the comparison of this study with historical studies. Dr. Bucher responded that the issue highlights a perplexing aspect of the study when trying to bring a historical perspective to interpreting the tumor data. He noted several of the differences between the current study and previous studies, including lighting, food, housing, and exposure methods.

Dr. Harkema asked about the phantoms and activity of the animals affecting the dose they received. Dr. Capstick deferred the answer to the dosimetry talk. Dr. Harkema also commented about the lighting, noting that lighting studies on plants by other researchers are ongoing.

[m]The slides and video of Dr. Capstick's presentation on the reverberation chamber system for RFR exposures are available at https://ntp.niehs.nih.gov/go/Presentations_RFR (slides) and https://doi.org/10.22427/NTP-VIDEO-47 (video). Web links updated September 24, 2018.

Dr. Felter asked about the basis for choosing the different radiofrequencies for mice versus rats. She asked how frequency selection applied to animals of different sizes. Dr. Capstick deferred the answer to the dosimetry talk.

Dr. Kiourti asked about the statistical variation of animal sizes and weights. Dr. Capstick deferred the answer to the dosimetry talk.

Dr. Cline asked Dr. Capstick to elaborate on the ambient noise within the rats' hearing range. Dr. Capstick said that the GSM noise was measured, and no components were above 14 kHz. He said that high-frequency noise emanating from the air conditioning equipment was not measured. Efforts were made to keep the stirrers well lubricated to minimize potential noise.

Dr. Lin asked about the GSM noise, and how it was transmitted into the chambers. Dr. Capstick replied the GSM noise was generated inside the chamber, but its origin was unclear, and efforts to dampen it were unsuccessful. Dr. Lin wondered if the noise was instead introduced from the electronics and power-transfer systems.

Dosimetric Considerations for Rodents Exposed in Reverberation Chambers

Dr. Capstick briefed the panel on dosimetry used in the cell phone RFR studies.

Dosimetry in the fields of health physics and radiation protection is the measurement, calculation, and assessment of the internal exposure to the body, expressed in Watts per kilogram (W/kg). Directly measuring SAR in a subject, human or animal, is not possible, so SAR is calculated using numerical simulations and is validated in homogenous experimental phantoms. High-resolution, anatomical models were used to determine numerical dosimetry, with tissue parameters based on published databases. Ultimately, the appropriate frequencies were determined to be 1,900 MHz for mice and 900 MHz for rats to obtain a more uniform SAR distribution. Dosimetry in the reverberation chambers was calculated based on generation of a homogeneous, isotropic field, using Rayleigh-distributed, temporal variations. Exposure-environment measures used representations employing the random plane-wave method and the 12 plane-wave method.

An automated watering system was designed to ensure that no energy was absorbed by water, which would cause a dose-dependent elevation in drinking water temperature. Also, the system was designed to avoid increased SAR or RF burns to the animals, which could deter them from drinking.

The isotropic field employed ensured minimum variation in whole-body SAR with posture. Variation in organ-specific SAR was also taken into account. Dr. Capstick also presented details regarding uncertainty and variability estimates. Full details on the dosimetric considerations are included in Dr. Capstick's online presentation[n].

[n]The slides and video of Dr. Capstick's presentation on the dosimetric considerations are available at https://ntp.niehs.nih.gov/go/ Presentations_RFR (slides) and https://doi.org/10.22427/NTP-VIDEO-48 (video). Web links updated September 24, 2018.

Questions for Clarification

Dr. Eaton expressed continued confusion about the units of SARs. Dr. Capstick explained that SAR is measured in watts per kilogram (W/kg) and that the limit for human exposure is SAR averaged over a 1 gram (g) or 10 g cube. He described how SAR was calculated in mice and rats over smaller cubes scaled to the relative adult weights. He explained that the measures in decibels (dB) used is a logarithmic ratio that can be related to either the whole-body average or the peak SAR. He explained how SAR sensitivity, the SAR per unit of electric field strength, is calculated.

Dr. Eaton said that although not the focus of the current studies, the data would be used for risk assessment at some point. He asked if anyone had derived modeled dosimetry in humans based on behaviors. Dr. Capstick said much work was ongoing in that area, particularly on exposures in children and device placement on the body.

Dr. Felter asked for clarification about how mass affects the measurement of SAR and if surface area has an effect. Dr. Capstick explained the concept of whole-body average SAR as an average over the mass. So, the larger the animal, for a given whole-body SAR, the more power is absorbed. He described the difference between organ-based SAR and whole-body SAR. His answer to the question about surface area explained that the ratio of surface area to total mass affects an animal's thermal regulation — a larger ratio means the animal can cool itself more quickly.

Dr. Kuster remarked that the study was run under the assumption that the fields locally induced in the tissue are the biologically relevant parameters, not the total absorbed power or whole-body averaged exposure. He noted that SAR and the square of the E-field are directly related, whereas the square of the local H-field (magnetic field) is sufficiently related for uniform exposures. As little is known about the radiofrequency sensitivity of specific tissues, the exposure was optimized for maximally uniform local E-field and H-field exposures.

Dr. Lin asked for more detail on organ-based SAR and whole-body-based SAR as it related to the figures Dr. Capstick presented on individual organ SAR differentials from whole body.

Dr. Melnick, retired NIEHS/NTP scientist and public attendee, was recognized by the chair for a question. He was concerned about the exposure of some of the sub-tissues in the heart. Dr. Kuster explained that the anatomical models provided a good proxy of exposure for different body regions and tissues, but no effort was made in this study to examine sub-tissues.

Dr. Felter asked about the pups, which were housed with the mother until weaning. She indicated her understanding was, when pups are clumped, their SAR can be increased, but when pups are apart, their exposure is similar to that of the dam. She asked why their estimated exposures would not be higher, given their much smaller body weight. Dr. Capstick explained that in terms of body weight and length, the pups are on an upward curve and the dams are on a downward curve, ending up at approximately the same SAR sensitivity.

Reverberation Chamber System Validation and Verification

John Ladbury from NIST briefed the panel on validation and verification of the reverberation chamber system. He provided background information on NIST and described the ideal characteristics of a reverberation chamber. The validation and verification plan emphasized

uniformity of temperature in the phantoms, probe field, and antenna power. Validations were performed in 2007, 2012, and 2015. The standard deviation for the loaded chamber field uniformity was 1.3 dB. Calibration was performed with radiofrequency field probes. Signal quality was within standard parameters for communications standards. Full details on the reverberation chamber system validation and verification are included in Mr. Ladbury's online presentation[o].

Questions for Clarification

After remarking about the robustness of reverberation chambers, Dr. Lin asked why the reverberation chambers had not been built in Chicago. Dr. Bucher explained that the system was assembled through contractual arrangements with various organizations, including IT'IS. Mr. Ladbury noted, although commercial reverberation chambers are available, they are designed primarily for electronics testing, and at the time, none were available for biological testing.

Dr. Cline asked if he was correct that no measurements were taken in the control chambers. Mr. Ladbury confirmed that no measurements were made in the control chambers. Dr. Capstick noted field probes were placed inside the control chambers and noise levels of the measurement system were recorded throughout the study.

Thermal Pilot Studies of Cell Phone Radiofrequency Radiation

Dr. Wyde presented information about the 5-day thermal pilot studies at SARs of 4 to 12 W/kg in mice, young and aged rats, and pregnant rats — 10 studies. The studies were designed to evaluate a wide range of SARs to determine the threshold for potential thermal effects of cell phone RFR, the impact of animal size and pregnancy on body temperature, and the potential effects of RFR exposure on pregnancy in rats. Body temperatures were collected via implanted microchips at multiple time points over 5 days.

In the mouse studies:

- No thermal effects were observed at SARs up to 12 W/kg regardless of age, sex, or modulation.
- 5, 10, and 15 W/kg were selected for 28-day studies.

In the rat studies:

- Lethal effects and excessive increases in body temperatures were observed at 10 and 12 W/kg.
- Increased early resorptions and decreased body-weight gain in pregnant dams were observed at 12 W/kg GSM.
- Based on those data, SARs of ≥10 W/kg were not recommended for further study in rats.
- 3, 6, and 9 W/kg were selected for 28-day studies.

[o]The slides and video of Mr. Ladbury's presentation on the validation and verification of the reverberation chamber system are available at https://ntp.niehs.nih.gov/go/Presentations_RFR (slides) and https://doi.org/10.22427/NTP-VIDEO-49 (video). Web links updated September 24, 2018.

Questions for Clarification

Dr. Adler asked whether body temperatures were measured at night, when rodents are eating, metabolically more active, and likely to have diurnal variation in body temperature, or only during the light cycle. Dr. Wyde said they were measured only during the day, and all measurements were made within 2 – 3 minutes of system shutdown to minimize the effect of heat loss. The temperature decay rate of an animal with elevated temperature was not independently measured, although some preliminary studies with the thermal sensors were done. Dr. Adler asked if any other physical parameters were measured, such as respiratory rate. Dr. Wyde said the goal was to examine only gross effects in body temperature, body weight, and survival, with no provision for histopathology. Some additional measures were performed in the 28-day studies. Dr. Adler pointed out that rodents acclimate quickly to environmental changes so that differences occurring at 5 days might not be detected at 28 days. The pharmaceutical industry prefers these measurements be done in 5-day studies because they can understand what additional systems are perturbed by the external influence before the animals reach steady state.

Dr. Felter asked why the 10 minutes on, 10 minutes off standard was chosen, and whether any experiments had been conducted with longer exposures. Dr. Wyde said that no other exposure lengths had been explored. Ten minutes was considered sufficient to allow for thermal regulation. The intermittent exposure was considered important to determining response to the RFR exposure, while the 10-minute exposure was somewhat arbitrary.

Dr. Kiourti asked about the implanted temperature sensors and how they communicated with the reader. Dr. Capstick confirmed that the system was radio-frequency identification.

Dr. Lin asked what other temperatures would be monitored if the experiment were to be repeated. Dr. Wyde said that NTP is considering some follow-up studies using data loggers to collect information in real time during the exposures.

Dr. Barnes asked if distortion of the fields with the sensor under the skin were possible. Dr. Kuster said that had been evaluated, and no distortion or interference with the measurements was apparent.

Dr. Rinke asked if the same rodent strains were used in all studies. Dr. Wyde said yes.

Dr. Gamboa da Costa from FDA asked whether some important information regarding the temperature of the main organs might have been missed. Dr. Wyde replied that was possible. Dr. Lin pointed out that the hottest spot was at the tail, so anatomy should be considered when determining where to implant the temperature sensor. Dr. Capstick noted that in his previous presentation showing the tail as a hot spot, it was the SAR distribution that had been modeled, which is not necessarily directly related to temperature distribution in the animal.

Dr. Barnes asked if use of an infrared camera had been considered. Dr. Kuster said that some investigators had tried to use thermal cameras in dosimetry, but they lacked the needed sensitivity.

Oral Public Comments on Technical Aspects of the NTP Exposure System

Dr. Eaton identified the written public comments received and presented a list of those public commenters. He described the format for presenting the oral public comments; five public commenters made oral comments on the exposure system.

Theodora Scarato, a private citizen, addressed the unique vulnerability of children to RFR, and the ever-increasing combined RFR exposures to the public. Cell phone use is now widespread, and they and other wireless devices are often used near the body. Pregnant women and children are exposed at much higher levels. Children, with thinner skulls and smaller heads, are much more vulnerable to RFR energy deposition. Published research modeling children's exposure shows that children's heads and brains are proportionally more exposed compared to adults. The use of multiple devices can increase SAR, as does the presence of metal inside or outside the body. The public is unaware that phones and wireless devices emit radiation, or that health concerns are associated with the exposures.

Dr. Olga Naidenko presented comments on behalf of the Environmental Working Group (EWG). She expressed EWG's support for NTP and NIEHS for having embarked on the absolutely essential cell phone RFR study and its appreciation that the first part of the study had been completed. EWG believes the exposures are relevant to people and to the exposures people are facing today. The study was conducted in 2G technology, whereas today 3G and 4G are in use, with 5G being rolled out. EWG's position is that the science currently in hand must prevail. EWG believes the next generation of exposure studies should increase emphasis on biological factors. The recent National Institute on Drug Abuse's study is a good example of research designed to elucidate short-term, immediate, and subtle effects such as changes in metabolism and in calcium-channel transmission and impacts on blood-glucose metabolism.

Dr. Devra Davis presented comments on behalf of the Environmental Health Trust (EHT). The exposure system is an important, positive study that was well executed under difficult conditions. She noted, however, that the exposure system used does not reflect current exposures. Historical controls are not relevant in the study; the only relevant controls are those from the study, and using historical controls from other NTP studies for comparison is a mistake. With respect to SAR values, basing guideline limits on average tissue volume data is inaccurate, as body parts are not cubes. She pointed out several issues for disagreement with NTP's study: The NTP study does not account for the multiple exposures experienced every day and cannot clarify what is happening in the occupational workforce, where RFR levels are much higher. The NTP study will not be relevant to 5G. She believes the whole-body approach taken in the NTP study is appropriate. French studies of exposures related to phones placed beside the body have shown much higher levels than those permitted by the FCC.

Dr. Kuster asked Dr. Davis why she believes the NTP study did not cover multiple exposures, noting that the local exposure levels used were higher than actual exposures from multiple exposure sources, even higher than occupational exposures. Dr. Davis said that current smartphones can have as many as four different antennas operating simultaneously, and that the synergy that occurs when electric and magnetic fields are combined with radiofrequencies or chemicals cannot be evaluated in a study like the NTP study. The real world is complicated, and studies such as the NTP study cannot capture that complexity. She stated the use of the technology has exploded and the capacity within experimental models to fully approximate

human exposures is not available, noting little information is available about the impact on human health today and in the future. Children are routinely exposed to RFR devices in close proximity.

Kevin Mottus spoke for the California Brain Tumor Association, which supports individuals who have developed brain tumors from cell phone radiation. NTP is to be thanked for embarking on the study and following it through so conscientiously. The study reflects what is being seen in the real world, particularly DNA damage related to the carcinogenic effect. The association works not only with brain tumor sufferers, but also with people who have become sick from RFR and microwave exposures. The NTP study and the Ramazzini study offer biological confirmation of the cellular effects observed in human studies for years. Wireless should be reclassified as a Class 1 human carcinogen. The NTP study shows a clear increase in brain tumors in the areas that get the most cell phone use — the frontal lobe, cerebellum, and temporal lobe. Brain cancer is now the number one cancer in children 15 to 19 years old and is one of the top three cancers up to age 39 years, reflecting an epidemic. Mr. Mottus was critical of FDA's critiques of the NTP study. Addition of 5G high-frequency transmission on top of low-frequency 3G and 4G will result in more disease. The use of multiple devices and frequencies will result in a microwaving of the U.S. population. He stated the FCC is hiding health effects of exposures and exempting new technologies from environmental review. He believes FCC is an industry-compromised organization and that NTP should take a stand against such compromise and insulate itself from industry influence.

Dr. Paul Heroux from McGill University was the final public commenter. He believes the NTP reverberation chamber delivered the test animals a stable challenge over a specific, integrated time frame. The variation of ± 2.5 dB quoted in the report, although excellent performance, could have been reduced by using larger chambers, so that the objects would occupy less of the total chamber volume. The study shows its age by its overemphasis on heat. The finding of lower survival in the non-exposed animals is not simply an artifact and has been borne out in other large animal studies. Another interesting aspect is that the survival advantage effects are stronger in males than in females. The NTP studies do not mention control of the background extremely low frequency environment. The effects of GSM and CDMA differ, so the details of the exposure are significant and important.

Peer Review Comments on the Reverberation Chamber Exposure System

Dr. Barnes, the first peer reviewer, felt the study was very well done in terms of accomplishing what it set out to do. With SAR as the critical parameter to define, NTP did a very good job of determining the exposure distributions and confirming the average values were as stated. Those elements were well tested and monitored throughout the studies. If the studies were designed today, however, Dr. Barnes said a variety of additional experiments could be conducted and additional parameters could be controlled. For example, translations from physics to chemistry and chemistry to biology could be built into future studies. Examining problems of feed-forward and feedback loops in more detail should be incorporated. Overall, NTP is to be complimented on a very thorough study. Dr. Bucher asked Dr. Barnes to elaborate on the concept of feed-forward, as NTP is interested in improving its studies. Dr. Barnes said feed-forward is related to elaborate communication systems inside the body, such as acupuncture points. An exciting development is the opportunity to convert electric and magnetic signals to biological signals in the chemical realm that the body already knows how to use.

Dr. Lin, the second peer reviewer, applauded NTP and NIEHS for having conducted the cell phone RFR studies because for the U.S. government to conduct such research and not leave it entirely to industry is important. He noted we are exposed to more and more RFR every day. The NTP study was the largest of its kind, was expensive, and took a long time to complete. The study showed that prolonged exposure to RFR levels, roughly three times current RFR exposure guidelines, could lead to tumor development, particularly schwannomas in the heart tissue of rats, and to some degree gliomas in the brain. He said the reverberation chamber (RC) apparently was selected a priori for the project and whether it is the optimal technology for the project or alternative, competing technologies were considered is unclear.

Descriptions in the report of what was implemented are clear and measurement techniques are accurate, within limitations. Although RCs are generally acknowledged to provide substantially uniform, average-field distributions in the absence of a test object, the bodies of rats and mice would be major radiofrequency energy absorbers, resulting in a very different interaction mechanism for fields inside the RCs. Free-roaming animals inside the cages would make the exposure field substantially less uniform compared to an empty RC. Although much effort was expended to achieve RF-field homogeneity and so-called “isotropy,” whether the RC approach had any advantage over simpler approaches is unclear.

He voiced concerns that mixing dB and linear scales is confusing and felt that describing uniformity using average-field distribution would have been more appropriate. He pointed out that field distortions introduced by the watering system do not appear to have been quantified.

Dr. Lin believes the use of liquid-filled, round, plastic bottles for the measures of uniformities in the RCs does not provide realistic simulations of animals’ body shapes, resulting in inaccurate measures of SAR variations. He speculated that differences in resonant absorption might account for the different observed biological responses in the rats and mice, and wondered what influence, if any, the differential wbSAR, psSAR or oSAR could have had on observed cancer incidence.

He believes the methodologies, paradigms, and protocols used in the studies were reasonable, but whether the studies are intended for cell phone or base-station RF exposures, and whether they represent near-field or far-field exposure scenarios, is unclear. The use of temporal and spatial averaging ignores anatomy-related responses of the animal as functions of time or age to RF SAR and SAR distribution. He noted the apparent lack of provision for physiological monitoring or animal behavioral observation during the 2-year studies. He raised concerns about the sonic noise in the chambers. Ear or tympanic temperature should have been measured periodically throughout the study to monitor core temperature. Seeing the SAR-dependent reports of schwannomas in rats is perplexing. The experiments specified whole-body exposure, and wbSAR was the key metric for exposure, but a correlation study of peak spatial SAR (psSAR) or oSAR with total observed primary tumors should be included in the report.

Dr. Bucher noted that one objective of the peer review is to identify how the report could be improved in communicating several of the issues Dr. Lin had raised. He said that some of the information Dr. Lin suggests has been in the day’s presentations, although not currently in the report, and welcomed suggestions for how best to encapsulate some of that information, particularly with respect to psSARs.

Dr. Kiourti, the third peer reviewer, congratulated NTP on a very thorough study. She had no major comments regarding technical aspects of the study. She asked how NTP could catch up with the technology, in general. Although the study delivers 100% of what had been promised, 2G is not even used today. She noted that the report should clarify that "exposures cycled between modulations every 10 minutes" means the cycling was between on and off for a given modulation, not cycling between the different modulations. She asked for more details about where the RF sensors were placed and why those locations were selected. She asked how the specific environmental conditions had been chosen and whether any differences would have affected the study's results. Although the animals were freely moving, they were still caged for 2 years, and she wondered whether that could have compounded stress. She asked for more details on the design of the antennas used, cage rotation, and how the NIST and IT'IS phantom studies compared.

Panel Discussion and Recommendations for Reporting of Chamber Design and Performance and Dosimetry Considerations

Dr. Eaton introduced the panel discussion section of the session. He said that, as a biologist, he appreciated the presentations detailing how the exposures were conducted. With the technologies having changed considerably since the studies were conducted, he asked whether the biological effects are likely to be better or worse now. Dr. Barnes replied that how the power is distributed as a function of frequency differs between the older technologies used in the study and the upcoming 5G. How to go from the physics to the chemistry to the biology can change, but there could be common responses, and elucidating the exact mechanisms affecting biology is very challenging.

Dr. Kuster addressed the question regarding bottles versus more anatomical phantoms. He stated that the numerical study provides the dosimetry and the purpose of the experimental study with the bottle phantoms was to validate the numerical dosimetry. First, the presence of any coupling between phantoms had been carefully evaluated, and based on that information, the cages were separated to exclude coupling. Thus, how the energy was scattered did not matter; the only concern was how the energy was absorbed. The bottle phantoms were optimized to absorb the same amount of energy as the rats absorbed. Dr. Kuster said that the dosimetry information has only recently been published. Dr. Lin noted that the animals' posture made a difference in dosimetry, and therefore a round bottle was not an animal-shaped body. Dr. Kuster explained the bottles were used to validate the numerical dosimetry and the uniformity of exposure throughout the chamber, and were not affected by the presence of the animals. The differences caused by the postures of the anatomical phantoms are addressed in the numerical dosimetry. Dr. Lin noted additional field measurements after installation of the watering system were not indicated. Dr. Kuster replied that the measurements were made at the end of the process, after everything had been installed. Dr. Lin said that the field inside the animal would depend on posture and geometry. Dr. Kuster agreed that that needed to be better explained in the report.

Dr. Cline mentioned that "dosimetry" is used incorrectly in the discussion. Dosimetry is the measurement of the dose, not a mathematical model of what the dose might be. Dr. Lin disagreed with that statement, noting the differences between ionizing and nonionizing radiation. Drs. Lin and Cline exchanged several comments on the point.

Dr. Lin added that, despite that 5G technology is being rolled out, 3G is still most relevant, as it remains what most people have in their pockets. He also discussed what the fundamental purpose and impacts of this study should be and the validity of this study.

Dr. Harkema asked if the design of the study (in 2007) was influenced or hindered in some way by constraining the timeline to a 2-year bioassay. Dr. Eaton added that NTP had been rather clairvoyant in the design of the study, as starting studies *in utero* was unheard of at the time, and now the importance of early-life exposures is recognized. Dr. Bucher pointed out that NTP tried to set the number of animals used to achieve maximum efficiency, with minimal animal use versus costs involved in increasing statistical power by adding population. He described some of the challenges associated with that approach.

Dr. Eaton recognized two public attendees: Dr. Davis from Environmental Health Trust and Dr. Melnick, retired NIEHS/NTP scientist. Dr. Davis commented on the issue of the relatively lower power of 5G, and whether it would result in fewer biological effects. She cited a study that reported the opposite effect — the weaker power but higher frequency was more biologically potent. Dr. Melnick noted that the objective of the NTP study, like all toxicology studies, was to test the null hypothesis. People were saying, “this is nonionizing radiation, there’s no possibility of adverse biological effect,” and therefore the study was designed to challenge that hypothesis. The assumption that no biological effect occurs holds for consideration of 5G technologies. With the current study having disproved the null hypothesis, testing the newer technology would be wise to determine if any health effects on the general population occur.

Dr. Eaton returned the discussion to consideration of the draft NTP reports. His sense was that the panel offered strong praise for the NTP program and for its designers and consultants for having constructed a very challenging exposure situation. He perceived no “fatal flaws” in terms of the exposures.

The panelists discussed uncertainties in the dose metric used in the studies. Dr. Felter alluded to the concept that the male rats experienced more effects because they are larger and pointed out that that should have resulted in lower exposure due to a larger body surface area. Dr. Barnes elaborated on the SAR dose metric and added that some additional properties were taken into account during dose measurement. Dr. Kuster noted the goal in the studies was to achieve uniform exposures of all tissues, to the extent possible. Dr. Felter said that the complicated nature of the dosing and dose metrics should be described in more detail in the reports.

Dr. Lin speculated about the best path forward in future studies. He noted that investing in a repeatable experiment might be appropriate before shifting the investigation to new technologies such as 5G.

The panelists and other experts discussed the issue of thermal versus non-thermal effects. Dr. Gamboa da Costa from the FDA urged caution about ascribing effects observed in the studies as non-thermal because monitoring temperature with fine granularity is difficult. Other panelists agreed that information to specifically rule out a thermal or non-thermal effect was insufficient. Dr. Barnes commented that a non-thermal effect is fairly ill defined.

Mr. Ladbury commented on the difficulty of moving the inquiry from reactive to predictive in terms of assessing the impact of newer technologies. He felt that the field would remain reactive to changing technologies for many years to come.

Dr. Whiteley stated that before studying 5G, gaining a better understanding of the dose-response biology of effects observed in the current studies, in the specific cell types that were affected, would be advisable.

Although panelists referred to the Ramazzini Institute study, Dr. Bucher cautioned that this meeting's intent is to peer review the NTP studies, so comparison to another study is probably not appropriate at the time. Again, an emphasis on clearly explaining dosimetry was brought up because the exposure system for the Ramazzini study was different. Concern was expressed that the broader field would make incorrect comparisons to this study if exposure were not clearly defined.

Day 1 of the proceedings was adjourned at 5:05 p.m.

L.4. Panel 2: Peer Review of Draft NTP Technical Reports on Cell Phone RFR

NTP's Toxicology and Carcinogenesis Studies: Experimental Design, Statistical Analyses, Genetic Toxicology Testing, and Hazard Determinations

Dr. Blystone provided an overview of the methodologies and approaches used in standard NTP chronic studies and in the cell phone RFR studies, including design considerations, and the animal models and numbers used: Hsd:Sprague Dawley SD rats and B6C3F1/N mice, 90 animals per sex per group. For these RFR studies, the exposure language differed from that for typical toxicology studies. He described several elements of the statistical analyses used in the studies, including the historical controls. He informed the panel about the NTP Levels of Evidence of Carcinogenic Activity, which form the basis for conclusions.

Questions for Clarification

Dr. Harkema asked if historical control data are available from the contractor, IITRI. Dr. Blystone said no. Dr. Harkema asked about the low and medium doses and what "additional lower doses were spaced accordingly" meant — according to what, he inquired. Dr. Blystone explained the variety of factors taken into account, including capturing a wide dose range, appropriately evaluating hazard identification, and considering route of exposure. Dr. Harkema asked how the low and medium doses were scientifically determined. Dr. Wyde explained that, due to system feasibility, only three exposure groups were an option. Extending the exposure range to 6 W/kg enabled NTP to challenge animals on a thermal basis, and extending the range to 1.5 W/kg brought the exposures to a relevant level near the FCC regulatory limit. Dr. Bucher followed by explaining that dropping the exposure range to even lower levels would have diminished the likelihood of detecting effects.

Dr. Harkema asked for clarification on the difference between "some" and "equivocal" in the levels of evidence. Dr. Blystone addressed the issue, noting that the "bright line" between the two was whether an observed effect was considered associated with the exposure. Responding to a question from Dr. Eaton, he added that historical control data and discussions among staff are used when making those decisions, but the determination ultimately relies on discerning positive versus negative effects.

Beginning with a question from Dr. Felter, a discussion ensued regarding the historical controls, particularly for the rats, which consisted of four studies, and including the concurrent controls in the overall historical control incidences. Dr. Felter felt that the historical controls should have been kept separate from the concurrent controls. Dr. Blystone stated that including the concurrent controls heavily weighted the historical control data for these studies, but both options were examined. Dr. Keith Shockley from NIEHS noted that the concurrent controls were used as part of the statistical testing, but the historical controls were not. Dr. Bucher said that in the next version of the reports, an appendix will delineate the studies included in the historical controls. The panel also posed questions regarding the use of a common control for the studies, which Dr. Wyde explained was due to space constraints and the cost of additional chambers. Dr. Bucher followed by saying that, if the studies were done again, a second control group would probably be included.

Dr. Harkema asked for more detail on the historical controls used in the mouse studies. Dr. Blystone said 11 studies, including the concurrent controls, were included. Dr. Lin said the historical controls were not relevant to the current studies due to differences in exposure, such as different lighting and different study designs. Dr. Harkema stated that, although the historical controls might not have been the most appropriate, they are still informative. Dr. Barnes pointed out that the assumption is that we are looking at a linear system with regard to dose response, but, in some sense, the historical controls are not free of exposure to RFR. He cautioned against treating historical controls as unexposed, as RFR probably was not measured and, therefore, they might not be true controls for comparison in these studies. Dr. Felter also cautioned against disregarding the historical control data, as they provide a wealth of information on variability in tumor response.

Dr. Rinke asked if the rodents used were from the same breeder or supplier as the historical controls were from. Dr. Bucher said that the rats were, and he believed that the mice were from the same breeder, although he was not certain.

Dr. Kaufmann asked what elements of neurobehavioral observations had been considered in the design of the studies. Dr. Blystone explained that, due to the constraints posed by the closed exposure chambers, detailed clinical observations were not possible. The nervous system was pathologically examined, with increased sectioning of the brain from three to seven slices.

Genetic Toxicology Studies in Mice and Rats Exposed to Radiofrequency Radiation

Ms. Kristine Witt briefed the panel on the genetic toxicology studies, describing the rationale for selecting the assays, the assay protocols (erythrocyte micronucleus assay, comet assay), the data analysis used, and how the data were interpreted. Subsets of mice and rats were assessed for genetic damage after 14 weeks (mice) or 19 weeks (rats) of exposure.

Questions for Clarification

Dr. Cline asked if comet assays had been performed on brain tissue. Ms. Witt replied that they had. Dr. Cline asked how the brain cell types were selected. Ms. Witt said that they selected the hippocampus, cerebellum, and frontal cortex, with no microscopic selection of particular cell types. Dr. Cline noted that several types of micronucleus tests are available and recommended that the assay be called the erythrocyte micronucleus assay in the report to avoid potential confusion.

Dr. Harkema asked how the brain sites for the comet assay were determined and how they were handled statistically. Ms. Witt said that each tissue type was considered independently and they were not combined for statistical analysis. She explained that the frontal cortex was selected because of the possibility of brain tumors, and the hippocampus and cerebellum were selected because they comprise large portions of the brain and cover a wide space for analysis. Dr. Harkema followed by asking if the comet assay was the most appropriate for comparisons to histopathology. Dr. Malarkey described the standard neurohistopathological evaluations and stated that there are no findings that correlate with the genetic toxicological findings. Dr. Bucher clarified that the animals taken for the comet assay were different from the animals used for interim histopathology.

Dr. Adler asked if the comet assay has a positive/negative threshold and whether a positive control was run. Ms. Witt said NTP animal studies do not have a positive control, but positive control slides with human cells exposed to a known genotoxic agent are run as an internal technical control. She added that the software does not delineate between positive and negative. No historical controls for the comet assay for these studies were included.

Dr. Lin asked whether other parts of the animals were assayed in addition to the neurological tissues. Ms. Witt said the liver and peripheral blood leukocytes also were assayed.

Relating to the positive predictive value of the erythrocyte micronucleus test, Dr. Eaton asked about the occurrence of false positives. Ms. Witt said that the last time a systematic review of the test was compared with a bioassay was 2000, which showed a 95% to 98% rate of positive predictivity. She noted the test has low sensitivity, but a positive response is meaningful, in both rats and mice. Ms. Witt is unaware of any chemical that induced micronuclei in vitro and does not induce carcinogenicity in vivo in 2-year studies.

Dr. Felter asked how the results from the comet assays were reported, in terms of positive, equivocal, and negative findings. She wondered what would be done if the data supported a trend in the opposite direction. She cited the example of a statistically significant decrease in the comet tail in the females in both modulations in the frontal cortex. Ms. Witt said that 2-sided trend tests are not conducted, so whether it was a statistically significant decrease could not be stated, although it might appear to be.

Pathology Peer Review Process for Two-year Studies of Cell Phone Radiofrequency Radiation

Dr. Amy Brix briefed the panel on the pathology peer review process used in the 2-year studies. She described the role of the study pathologist and outlined the steps in the pathology peer review process, including the Pathology Data Review (PDR), the audit of pathology specimens, the pathology quality assessment slide review, the Pathology Working Group (PWG), and the final steps to complete the process.

Questions for Clarification

Dr. Harkema noted that no place conducts the pathology process better than NTP, which sets the gold standard. He asked Dr. Brix to summarize the review process used with the lymphomas. She said that the study pathologist initially noted them in the report. During the PDR, items were flagged for review including the statistical tables, incidence tables, and anything unusually high

or low in the controls. All lymphomas diagnosed in the mice were reviewed, and all tissues with neoplasms were automatically reviewed. That information was then given to the PWG. She said the conclusion did not change throughout the study. Dr. Harkema said it seems unusual to have two pathologists, one looking at males, one looking at females. Dr. Brix agreed, although it was necessary because of the size of this project. Dr. Harkema also asked where the study pathologist was located for these studies. Dr. Brix replied that IITRI used a subcontractor as a pathologist and did not have one on site.

Dr. Lin asked about blinding at the study pathologist and pathology review levels. Dr. Brix said that slides are not blinded at the study laboratory, because it is not considered as sensitive a read if something is seen when blinded. Slides are also not blinded during the quality assurance (QA) review. At the PWG level, blinding is used and PWG participants are unaware of the study or QA pathologist calls. Dr. Lin noted that at the study pathology level, the pathologist would have known whether a tissue came from exposed or control animals. Dr. Brix confirmed that impression and added that NTP follows the industry standard for such studies, and non-blinding is the most scientifically appropriate method. She said that the pathologists are evaluating a biologically complex system, and they must be able to compare treatment-related findings to control incidences to distinguish which findings actually differ. Dr. Lin and Dr. Brix exchanged several comments on the issue. Dr. Bucher noted that the argument is not unique to NTP, having persisted among pathologists for a long time. Dr. Harkema said that even pathologists do not take the issue lightly and the entire process has been rigorously reviewed. He believes that in this case, the peer review, which is the most unbiased, is at the correct level in the process. If any study pathologist bias were to occur, it would be caught at the peer review level.

Dr. Cline asked how the rest of the head, aside from the brain, was assessed. In particular, he wanted to know if the vestibular system and auditory nerve were included. Dr. Malarkey said they were not assessed in the mouse, but some exploration in the rat was conducted.

Peer Review of NTP Studies in Mice of Cell Phone RFR

Charge to the Panel

Dr. Blystone presented the charge to Panel 2, addressing the draft NTP Technical Report TR-596, Toxicology and Carcinogenicity Studies in B6C3F1/N Mice Exposed to Whole-Body Radiofrequency Radiation at a Frequency (1,900 MHz) and Modulations (GSM and CDMA) Used by Cell Phones. The panel was charged to:

- Review and evaluate the scientific and technical elements of the study and its presentation
- Determine whether the study's experimental design, conduct, and findings support NTP's conclusions regarding the carcinogenic activity and toxicity of the test agent

Oral Public Comments on Technical Aspects of NTP Studies in Rats and Mice

Dr. Eaton acknowledged the written public comments received and presented a list of those public commenters. He described the format for the oral public comments to be delivered. In the second session, nine oral public commenters on the NTP studies in rats and mice were accommodated.

Ms. Scarato drew a distinction between FCC human exposure limits and safety guidelines. Proper safety testing has never been completed on chronic, low-level exposure. The NTP findings of increased cancerous and pre-cancerous lesions confirm that the FCC limits are non-protective. The technical reports should include the regulatory limits of other countries and summarize that the FCC limits are far higher. Co-exposures should also be taken into account, with studies showing synergies included in the reports. The reports also should refer to studies addressing changes in the permeability of the blood-brain barrier related to cell phone use, decreases in brain cells resulting from prenatal exposures, and behavioral issues related to prenatal exposures. The reports should include information on worldwide governmental actions to reduce RF exposure. Maryland and California have acted to reduce RF exposures. The mouse technical report omitted NTP data presented in 2016 regarding DNA damage analysis and this data should be added back in. Similarly, reference to the conclusion by the World Health Organization's International Agency for Research on Cancer was included in the 2016 report but not in the 2018 draft technical report, and it should be added. Discussion of the Ramazzini studies should be added to the technical reports, as should the concordance of the observations of schwannoma in rats and lymphoma in mice, considering that we live in a world of multiple exposures. The U.S. government should act to limit public exposures.

Dr. Naidenko from the Environmental Working Group stated that NTP is in a unique position to study the biological effects of cell phone RFR exposures. She alluded to a company, Novocure, which has FDA approval to use electromagnetic fields (EMF) for treatment of glioblastoma. She described how EMF can impact biological systems, showcasing the extremely complex biology involved, including the effects investigated by NTP and considered by the peer review panel.

Dr. Davis spoke on behalf of colleagues at Hebrew University. She noted that this 3-day review was unprecedented. She appreciated the explication of the blinded pathology review. The NTP study is not a lifetime study, ending at 2 years, and 60% of all cancers in humans occur after age 60. The rodent studies end at the equivalent of age 60. She recommended using the NTP study's controls and not historical controls. She noted that the baseline rate of cardiac schwannoma was quite low, even in historical controls. She recommended reexamining the data on reproductive endpoints and birth weight impacts. She added several other detailed recommendations. She further discussed the Ramazzini study and presented relevant conclusions from the study. She presented data from several other recent studies, suggesting reproductive endpoint effects of RFR exposures and increasing rates of brain tumors in the United States.

Dr. Kuster said that Dr. Davis' comparison of exposures was "apples and bananas," and that the NTP study is conservative with respect to simulating the exposure, independent of usage. She agreed, but pointed out that phone testing methods vary, with many agencies testing them in a holster away from the body, which would reduce exposures and is an out-of-date method. The French, she observed, test phones in close proximity to the body.

The next oral public commenter was Dr. Marc Arazi from the Phonegate Alert Association in France, an organization devoted to sharing technical and scientific information on cell phone radiation and formulating safety recommendations. He commended NTP for using high SAR levels in its studies and found the results in several organs particularly important to understanding the risks associated with RFR on the whole body, not just the brain. He described a 2016 report on tests by the French government called Exposure to Radiofrequency and Child Health. Data showed that many of the most popular phones in the European market exceed

regulatory RFR limits. Another new report showed that RFR sensitivity is a real and widespread illness. He emphasized that focusing on realistic use of cell phones by users and implementing simple measures to protect the billions of users in the world are necessary.

Dr. Annie Sasco is a former Unit Chief at the World Health Organization's International Agency for Research on Cancer and retired director of research at INSERM (*Institut national de la santé et de la recherche médicale*, the French National Institute of Health and Medical Research). At this review, she spoke on her own behalf. She described her background and education as a cancer epidemiologist. She said that over her 35-year career, the situation with regard to cancer had not really improved. She noted that today hardly anyone on the planet has not been exposed to EMF radiation, making the demonstration that EMF exposure is a carcinogen difficult. Focusing research on those most heavily exposed and exposed for long duration will be important. Most case-control studies of that nature have found increased risk. With the challenges to epidemiology in the area, experimental studies such as those undertaken by NTP will be important going forward. She suggested using a larger unexposed group to avoid the need to use historical controls. With the need to rely on experimental studies in the future, the research needs to accelerate to keep up with introduction of new technologies. She commended the NTP studies, which she described as large, well conducted, and methodologically sound, providing more evidence of RFR carcinogenicity. She said the situation has evolved from precaution to prevention, as evidence has accumulated.

Dr. Lin reiterated his assertion that there are no unexposed animals.

Kevin Mottus from the California Brain Tumor Association wished to highlight the comments of Dr. Lennart Hardell, an oncologist and leading authority on wireless radiation and cancer. His comments pertained to the NTP studies and others. He cited clear evidence of several cancers including glioma and some evidence of other cancers, and the International Agency for Research on Cancer recommendation that RFR be classified as a Group One carcinogen to humans. Mr. Mottus then added his own comments. He said the mechanism behind RFR and cancer is now known, and that evidence is mounting of brain cancers in the frontal lobe, the cerebellum, and the temporal lobe — the brain regions that receive the most cell phone radiation. He believes FDA should take quick action to rein in FCC, which is dominated by industry, especially with the rollout of 5G and its thousands of transmitters. He said everyone should be alarmed, because the situation is not a public health crisis in the making, but is going on currently, and could become horrific in the near future.

Dr. Young Hwan Ahn from the EMF Research Committee of the Korean Institute of Electromagnetic Engineering and Science spoke by phone from Korea. He briefly introduced himself and described his background as a neurosurgeon. He described classification of tumors of the nervous system, such as glioblastomas and schwannomas, which comprise about 8% of brain tumors. Cardiac schwannomas are extremely rare. Despite that fact, the NTP study reports have drawn special attention to tumors of the nervous system. If life-span RF exposure can cause increased incidence of tumors of the nervous system, regardless of statistical significance, attention must be paid to the carcinogenic potential of RFR in humans. He stated the NTP study was well organized, with the survival of the sham-exposed group the most significant drawback.

Dr. Heroux from McGill University suggested that page 13 of the rat document be reworked to group the results according to tissue types, which would highlight that brain and nervous tissues

showed carcinogenic action at various stages and in various locations in the body. He felt that health effects in rodents would emerge later in life, past the 2-year bioassay point. If bandwidth is increased, the chances of interferences and consequences to biological systems also increase. He concurred with Dr. Lin's point that there are no controls, in that the rats thought of as controls have in fact been exposed to extremely low frequency radiation. Genetic drift caused by exposure is also a problem, with potentially serious consequences that are not discussed in the literature.

Dr. Ronald Melnick, a retired NIEHS/NTP toxicologist and one of the original scientists associated with the NTP cell phone RFR studies, spoke on the utility of the NTP data on cell phone RFR for assessing human health risks. He provided background information about the history of the project, which began with the original nomination in 1999. The initial objectives were to test the null hypothesis — that cell phone RFR at non-thermal exposure intensities is incapable of inducing adverse health effects — and to provide dose-response data that could be used to assess potential human health risks for any detected adverse effects. The results described in the technical reports "show quite clearly" that the null hypothesis has been disproven, with many adverse effects identified. Dr. Melnick delineated the adverse effects observed and described their levels of evidence of carcinogenicity. He pointed out that even a small increase in cancer risk could have a serious public health impact due to the widespread use of cell phones.

Dr. Lin asked Dr. Melnick to discuss how the decision was made to use one common control in the studies. Dr. Melnick said that comparing exposure groups to sham controls was ideal for space constraints and feasibility. In hindsight, he said, including additional control groups might have been better. With the provision of 90 animals per group, NTP felt sufficient power was achieved with the common controls. He acknowledged the historical controls were difficult to work with due to differences in housing and the exposure system; however, they were used to demonstrate how rare a particular event was in the NTP database, not for direct comparisons.

Results of the NTP Studies of Cell Phone Radiofrequency Radiation in B6C3F1/N Mice

Dr. Wyde briefed the panel on the results of the 28-day prechronic toxicology studies and the 2-year toxicology and carcinogenicity studies in mice, which included 14-week interim evaluations of histopathology, genetic toxicity, and hematology.

The draft report's preliminary conclusions (subject to peer review modification) were as follows:

- In the male mice exposed to GSM-modulated cell phone RFR at 1,900 MHz, there was *equivocal evidence of carcinogenic activity*, based on combined incidence of fibrosarcoma, sarcoma, or malignant fibrous histiocytoma in the skin, and incidences of alveolar/bronchiolar adenoma or carcinoma (combined) in the lung.
- In the female mice exposed to GSM-modulated cell phone RFR at 1,900 MHz, there was *equivocal evidence of carcinogenic activity*, based on incidences of malignant lymphoma (all organs).
- Exposure to GSM-modulated cell phone RFR at 1,900 MHz did not increase the incidence of any nonneoplastic lesions in male or female B6C3F1/N mice.

- In the male mice exposed to CDMA-modulated cell phone RFR at 1,900 MHz, there was *equivocal evidence* of carcinogenic activity, based on incidences of hepatoblastoma of the liver.
- In the female mice exposed to CDMA-modulated cell phone RFR at 1,900 MHz, there was *equivocal evidence of carcinogenic activity*, based on incidences of malignant lymphoma (all organs).
- Exposure to CDMA-modulated cell phone RFR at 1,900 MHz did not increase the incidence of any nonneoplastic lesions in male or female B6C3F1/N mice.

Questions for Clarification

Dr. Andrews-Jones asked for clarification about the incidence of malignant fibrous histiocytoma, first regarding the historical control incidence in the female mice and the locations involved. She noted that the incidences were primarily on the tail, with one on the pinna, and commented that those were areas of the mouse that received the most exposure. Dr. Brix said that she reviewed five previous studies with incidences of that particular tumor, and found 13 animals with malignant fibrous histiocytomas, with a total of 14 tumors. Of the 14, 10 were on the tail and 1 was on the ear pinna. In the current study, only one tumor not on the skin occurred, which had metastasized throughout the mesentery (a sham control animal). The rest were on the pinna or the tail in exposed animals, none of which had metastasized.

Dr. Rinke asked Dr. Brix where the tail tumors were located. Dr. Brix said that she saw pigment in the lesion of several of the tumors, indicating that they were near the tattoo, which would be in the proximal half of the tail.

Dr. Andrews-Jones asked whether the tail was examined only if a gross lesion was present. Dr. Brix said the lesions were mostly gross lesions. Although the tail is not collected as part of the standard protocol for histological examination, it was examined in every animal, grossly.

Dr. Kaufmann asked if the histopathology sectioning of the brain differed between rats and mice. Dr. Brix said that seven sections were taken from both rats and mice, so they were comparable.

Regarding the GSM female mice with a dose-dependent increase in malignant lymphomas, Dr. Lin felt that the statistics were fairly clear and wondered how the decision was made to classify the findings as equivocal. Dr. Wyde said the statistically significant increase had been seen only in the low- and mid-dose groups, with no significant trend test, so no SAR-dependent trend was observed. The top dose group showed no statistically significant increase, and the incidences fell within the historical control range. Thus, the findings were classified as equivocal.

Dr. Corcoran asked whether, in past NTP chemical studies, instances had been observed of statistically increased incidences of tumors in low- and mid-dose groups, but not in the high-dose group, and a conclusion was reached that was not equivocal. Dr. Wyde said that in over 500 NTP Technical Reports, he was sure that had been done, although he could think of no specific examples. Dr. Blystone said there were such cases, and added that the calls depend on several factors, such as survival. Dr. Corcoran said he would return to the topic of linearity versus nonlinearity in his later comments.

Noting that the comet assay was positive for the frontal cortex at 14 weeks in the mice, although evidence of brain tumors at 2 years was absent, Dr. Adler asked about the latency for DNA

damage-induced brain tumors in mice. He asked whether the study was adequate to show it, or whether there was another explanation for why a clear genetic damage signal did not have an outcome of positive brain tumors. Dr. Wyde said that a positive comet assay finding did not guarantee an increase in tumor incidence following 2 years of exposure. The comet assay is a snapshot in time and would not take into account DNA repair and other such processes. He reiterated that findings are rendered "under the conditions of this study." Dr. Eaton clarified that the micronucleus test was negative, although the comet assay was positive.

Dr. Rinke said he would have found it advantageous if the preneoplastic lesions had also been considered for the lymphomas. Dr. Brix said that lymphoid hyperplasias in the spleen were similar in the controls and dose groups, so abnormality was not indicated.

Dr. Barnes commented that his group's data indicate that nonlinearity is important, and provided examples.

Dr. Felter asked if time to first tumor is part of NTP's considerations for making carcinogenicity calls and recommended that it should at least be included in the discussion. She said that tumors were observed earlier in control animals relative to exposed animals in this study. Dr. Wyde cautioned against using latency period as a deciding factor, as tumors are generally not noted until an animal is necropsied; therefore, the tumor could have developed before that. Dr. Felter asked if that held true for skin tumors as observed in the study, which might have been grossly visible. Dr. Brix added that the tumors were probably not the cause of the animals' death and clarified that NTP only reports tumor incidence at study termination unless an early death occurs.

Dr. Harkema asked Dr. Brix for her reaction to the low lymphoma rate in controls. Dr. Brix replied that a second control group would have helped. Dr. Harkema asked what the second control group would have looked like, and whether any considerations would be made about the potential protective effect of the chambers in regard to controls. Dr. Brix replied that they could not address whether that was a factor. They agreed that a control group outside of the reverberation chamber would have answered some of the associated questions.

Dr. Andrews-Jones asked whether any consideration was given to going back and trimming in the tails from all animals in the area where gross lesions had been seen, to increase confidence that no microscopic lesions were missed. Dr. Brix said they had not done so, but all tails were looked at grossly, although not microscopically.

Presentation of Peer Review Comments

Dr. Harkema, the first peer reviewer, stated the studies were well designed, justified, and executed. He suggested elements for looking at exposures beyond 2 years could have been added due to the potential for later appearance of tumors. Much has been learned from the presentations, and the additional information in them should be added to the report. He asked for a clearer and more concise description of the historical control data, including information on the 5-year window and specific comments on the studies that currently comprise the historical control database. He requested more details about noise levels and measurements, more information about time of day the mice were exposed and the lighting used during exposure, and more discussion of the strengths and limitations of the studies and remaining data gaps. Discussion of the practice of putting lesions in "bins" also would improve the report. Although Dr. Harkema agreed with the conclusions of equivocal evidence in the 2-year study, he requested

better explanation of the rationale behind the equivocal call and why it did not rise to the higher category of some evidence. He recommended adding a section comparing the mouse and rat studies and asked for more clarity in the report on the justification for all doses, beyond just the high doses.

Dr. Wyde mentioned the statistical issues surrounding the distinction between 2-year and lifetime studies and pointed out that extending the study would naturally result in more common tumors arising. Dr. Harkema said that, in his experience with inhalation toxicology studies, a dramatic increase in tumors would have been missed if the studies had been cut off after 2 years.

Dr. Wyde said he would follow Dr. Harkema's recommendation regarding the historical controls. Regarding the noise, lighting, and activity issues, more information will be added to the report as suggested, as will more discussion of the equivocal findings and why they did not rise to a higher level. In terms of comparison between the rats and mice, Dr. Wyde said he envisioned a follow-up manuscript on that topic.

Dr. Corcoran, the second peer reviewer, commended NTP for conducting a one-of-a-kind study. Several key factors distinguish the NTP studies from previous studies of RFR radiation and rodents. He said that the study design was comprehensive and robust, with sound rationales for each factor selected, including the exposure system, chambers, animals, and parameters evaluated. He recommended the reports include a section on the strengths and weaknesses of the reverberation chamber model. The innovation of the exposure model demonstrates important advancements in the ability to study RFR. A review of the conduct of the study, which required a very large number of observations and measurements, yielded no apparent evidence to suggest that the study findings had been compromised — no significant issues were found with the conduct of the study.

He objected to use of the word "similar" in reference to body weights of male and female mice exposed to RFR for 2 years and sham controls. He questioned the standard error values of 0.00 in the results reported in Table G-1 and elsewhere. The report would be strengthened by more discussion of why the occurrence of lesions in sham controls fell at or below the low end of the historical control range, as well as discussion of how cumulative Type 1 error associated with the large numbers of comparisons was maintained at $P<0.05$. He urged more discussion of linear and nonlinear causation of cancer, and how it relates to RFR. He called for a more analytical approach to the equivocal level of evidence call, with a rubric of 10 to 20 factors and a weighting for each factor, which would lead to a weight-of-evidence determination. He questioned the use of historical control data and linearity of the dose response when making the level-of-evidence call.

Dr. Corcoran noted that Dr. Brix's presentation added important details about the pathology review process and recommended additions to the report. He felt the report would be strengthened by including instances in which significantly different pathology assessments were encountered. He said the report was parsimonious in acknowledging published findings and meeting quality standards and should expand discussion of selected published findings, some of which were noted in the public comments. Although not perfect, the study has enormous strengths, along with some challenges, and brings very high probative value, contributing a great deal to the existing body of literature.

Dr. Wyde noted that body weights are considered similar when they are within 10% of controls. He agreed to rework Table G-1 to reflect actual values; the 0.00 values occurred due to rounding. Regarding historical versus concurrent controls, he said that all panel comments would be considered as the report is finalized.

Dr. Shockley responded to Dr. Corcoran's comment on the Type 1 error, specifically pointing out the use of Dunnett's test for non-tumor data. He acknowledged that, when making hundreds of comparisons, some error is expected. NTP does not adjust for multiple comparisons with tumor analysis. He noted that NTP uses a weight-of-evidence approach in reaching its hazard conclusions, not a strict statistical decision rule. He said that several studies have examined false positive rates in NTP studies using all relevant information in reaching conclusions, and the results were equivalent to a $P<0.05$ to 0.07 level. Even though NTP is testing at the 0.05 level, the actual false positive rate — if the background tumor rate is low enough — would be lower than 0.05. He said he would try and address the issue in more detail in the report.

In response to Dr. Corcoran's comment on linear and nonlinear causation of cancer, Dr. Wyde said that, although there is an expectation of linearity, nonlinear effects do occur with some agents. Regarding the pathology, Dr. Brix noted no differences in conclusions between the study pathologist and NTP pathologists, and the majority of the differences were in terminology. Dr. Wyde said NTP would evaluate the more recent literature and would incorporate the material as appropriate, including the Ramazzini study.

Dr. Andrews-Jones, the third peer reviewer, also commended NTP for the design and execution of the study and for the rigor with which the pathology data were reviewed, which is the industry gold standard. She said she was struggling with the malignant fibrous histiocytomas in the skin, a rare tumor with a total incidence, including both GSM and CDMA exposures, of 11 in the male mice and 6 in the females in the treated groups, with 1 in the sham controls. She was still unclear about the historical control incidence in female mice. She appreciated the clarification about the location of where the tumor occurred in previous studies. The point that the tails were examined only if they had a gross lesion should be brought forward in the description of the lesion. The tumor incidence did not show a dose response, leading to the equivocal conclusion, but the incidences were higher than the historical control range, potentially elevating it to the level of some evidence. She noted that the report ultimately would be written not just for the technical and scientific community but for the public as a whole. Therefore, explanation of the methods and language should be more robust, with addition of a dictionary that would be hyperlinked. The challenge would be that it would need to be written in a format that a lay person could understand, with visual and graphic support.

Dr. Wolfe mentioned that a lay summary is prepared as part of the final report. Dr. Wyde thanked Dr. Andrews-Jones for her advice, particularly the idea of a glossary, which he suggested could be included as an appendix. He said the issue of the tail tumors being observed grossly would be elaborated further in the report.

Dr. Rinke, the fourth peer reviewer, also said that the study was very well done. He suggested more explanation of the 1999 nomination by FDA to put the ensuing years in more context. Regarding the malignant lymphomas, they were not deemed the cause of early death in the sham control group, and he wondered what the cause of death was and whether that could be elaborated. Regarding the historical controls, the procedures should be updated in the report,

particularly with the 5-year range explained further. He also would have liked to see additional control groups in the study. He said the malignant fibrous histiocytomas also raised a concern with him because they are such a rare tumor. More information on their location would be advisable, as they might have been more significant if they had been located closer to the body. He noted other rare tumors were not discussed in the report, and suggested a table of uncommon, rare tumors. He said that the hepatoblastoma is a very rare lesion, but the criteria employed might differ from his customary ones. He added several editorial comments.

Dr. Brix said she would rewrite the paragraph on the malignant fibrous histiocytomas based on Dr. Rinke's editorial comments. Regarding the areas on the tail, in several of the tumors, she noted the pigment could actually be seen. The other rare tumors, while deserving mention in the results, did not rise to the level of biological significance and thus were not brought forward to the discussion; however, they could be put in a table, as Dr. Rinke suggested. Dr. Wyde pledged to add to the discussion of the 1999 nomination and the ensuing timeline.

Ms. Pant, the fifth peer reviewer, as a genetic toxicologist, addressed those elements in the report in her review. She felt the study was well designed and conducted under robust conditions. She agreed an additional control group should have been included. The comet assay and the micronucleus assay are short-term studies, and the effects are not cumulative. As such, she wondered why sacrifice was delayed until 14 weeks after dosing began. The genetic toxicology studies were well done, following guidelines. She suggested that the comet assay results should simply be stated as "positive in comet assay," as opposed to breaking out according to organs. Regarding the historical data, she believed the concurrent controls were a better comparison for this study. She said that normally the genetic toxicology assays are conducted in 6- to 8-week-old animals, 10 weeks at the most, but in this study, they were conducted at 14 weeks, which could have an effect.

Ms. Witt explained that the reason for the 14-week time frame for the micronucleus studies was that the micronucleus assessments are routinely integrated into the 14-week toxicity studies, a standard practice that avoids the need to use additional animals. Length of time does not appear to influence the assay outcomes. She said that the overall call for the comet assay is positive in both males and females, with the location of response indicated.

Dr. Eaton noted that Ms. Witt showed a quantitative measure of degree of change in the comet assay, from marginal to the "hedgehog." The call, however, is yes or no. He wondered if it would be useful to comment on the degree of positivity in the positive assays. Ms. Witt replied that the strength of response is captured along the way, and NTP could review the P-value applied to the data. Dr. Eaton observed that having more information about a positive response beyond the yes/no would be helpful. Ms. Pant added that the negative control also would play a role.

Dr. Malys, the sixth peer reviewer, found the study extremely well done and thorough, and from a data perspective (his specialty), accommodated many statistical effects. That the goal of the exposure system was to normalize to the amount absorbed per body weight should be stated up front and clearly. That SAR is tissue-based should be emphasized. He was glad to see the level of care taken in the tests chosen for the many traits assessed throughout the study. He approved of the statistical methods used to account for litter effects. He agreed with Dr. Corcoran on the Type I error concerns (individual control versus global control) and requested clarification of the multiple-hypothesis testing correction and clarification that the multiple-source comparison

system kept P-values at the appropriate level. He appreciated Dr. Shockley's explanation of the issue and said it should be added to the report. He approved of including the historical controls. As NTP moves to design future studies, everything is becoming progressively more data driven, so as plans for new studies are made, the anticipation of weak effects should be taken into account. NTP should consider whether additional evidence can be used to support findings that are statistically, but not biologically, significant.

Dr. Shockley appreciated Dr. Malys' suggestions about controlling Type 1 error rates and taking litter effect into account.

In terms of statistical power, Dr. Malys asked if a better control could be included in the design, could power calculations be considered, and could a margin be added to turn the power calculation into a real result. He noted the mice that were not exposed to RFR experienced lower survival. He said that result stood and felt that it was important and warranted further discussion in relation to the level-of-evidence call. He believes the survival curve carries a lot of weight in these longer-term studies.

Panel Discussion and Recommendations

The chair introduced the session, noting that at the end of the discussion, Panel 2 members would vote on the conclusions for the draft mouse NTP Technical Report. Panel 1 members would not vote, but were available for technical consultation.

Dr. Eaton acknowledged the widespread praise among the panel for the basic design and validity of the studies. Considerable discussion was held about the role of historical controls and how they were used in the report. The nature of the dose-response relationship was another issue of concern, with some evidence of strong response at the lower doses and no response at the higher doses. He described the voting procedure:

- He would accept a motion and second to accept the draft report's conclusions as written.
- If there is a motion and no second, or if the motion is voted down, each conclusion would be considered and voted on individually.
- If the motion carried, the draft report's conclusions would be accepted as written, with no further action necessary.
- Panel members who vote no or abstain would be asked to explain their reasons for doing so.
- The chair would vote only in the event of a tie.

Dr. Eaton permitted an *ad hoc* comment from the audience. Dr. Heroux from McGill University said lumping all exposures, including GSM and CDMA exposures, would be allowable. He added that having no extremely low frequency magnetic field measurements is not acceptable because it was a real confounder in the data. Determining where the rats came from would be worthwhile so their exposures prior to the experiments could be estimated.

Drs. Eaton, Wolfe, and Bucher further explained the voting procedure.

Dr. Wolfe displayed the initial conclusions for the panel's consideration.

Dr. Cline commented on the nonlinear dose-response curves, citing two examples of the phenomenon. The mechanism for RFR is not necessarily known, but it is clear that linearity is not always the case.

Dr. Harkema asked that NTP staff summarize the factors behind each conclusion. Dr. Eaton said that would be appropriate, if voting on each conclusion individually were undertaken.

Regarding the skin fibrosarcomas, Dr. Whiteley said the classification had been challenged, and asked if NTP were to change it based on the panel's feedback, would it change NTP's conclusions? Dr. Blystone reiterated that the NTP recommendation was *equivocal evidence*. Dr. Whiteley said he was reacting to NTP's saying earlier that it would "take it under advisement," and asked whether that meant the treatment of the issue would be changed. Dr. Wyde said the statement meant the report would be added to. Dr. Wolfe further explained what the panel would be voting on.

Dr. Felter asked Dr. Brix about the relationship between the hepatoblastomas and the hepatoadenomas and hepatocarcinomas, and whether they are considered to be on a continuum. Dr. Brix replied that the liver tumors are considered individually and in combination. Hepatoadenomas and hepatocarcinomas arise from the same cell type, and hepatoblastomas can arise within a hepatocellular adenoma or carcinoma. The cell of origin is unclear, so there is a reason for combining them.

Dr. Andrews-Jones noted that nonlinear dose response in the mice could change the interpretation of the malignant fibrous histiocytomas and other tumors such as pituitary adenomas and carcinomas, for which a nonlinear dose response occurred. Dr. Barnes reiterated the dose response here clearly is nonlinear.

Dr. Eaton asked what the process would be to elevate tumors mentioned in the report and not included in conclusions. Dr. Bucher said it would be accomplished by motion.

Dr. Adler asked whether the statistical analysis for nonlinear response is different. Dr. Bucher cited pairwise comparisons and trend tests. He said that linearity of response is not always assumed in chemical findings. Dr. Adler asked if nonlinearity of response is taken into account in the NTP conclusions framework. Dr. Blystone replied that the conclusions are not necessarily designed to address nonlinearity, depending on other factors. Dr. Barnes added that, in addition to experimental data, at least two theoretical approaches can lead to the kind of nonlinear responses observed.

Dr. Eaton called for a motion to accept the recommendations in full as written in the draft report. Dr. Harkema so moved. No second was made, the motion failed, and consideration moved to the individual conclusions.

GSM-Exposed Males

The first conclusion was for the first bullet point under GSM modulation in the male mice, "*equivocal evidence of carcinogenic activity* based on combined incidences of fibrosarcoma, sarcoma, or malignant fibrous histiocytoma in the skin." Dr. Wyde explained that, although the incidences were outside the historical control range, no statistically significant increase occurred and no SAR-dependent increase in response was noted. This led to the *equivocal evidence* conclusion.

Dr. Andrews-Jones pointed out two incidences in the CDMA males were observed. Dr. Brix explained that the staff felt those incidences did not rise to the level of *equivocal evidence*. Dr. Rinke said he had been convinced that *equivocal* was appropriate for the tail tumors. Dr. Kaufmann agreed the evidence for a *some evidence* call was not sufficient.

Dr. Eaton called for a motion. Dr. Rinke moved to approve the conclusion as written; Dr. Corcoran seconded. The vote was 8 yes, 3 no, so the motion passed. Drs. Andrews-Jones, Felter, and Adler were the "no" votes. Dr. Andrews-Jones explained that she voted as she had because of the sheer number of tumors compared to so few in the historical control database. She felt the conclusion should have been *some evidence*. Dr. Felter said her reasoning was much the same and agreed the area between equivocal and some was very gray. Dr. Adler said he could not call it *equivocal* due to how much the historical control range had been exceeded.

The panel proceeded to the second bullet point under GSM modulation in the males, "*equivocal evidence of carcinogenicity* based on incidences of alveolar/bronchiolar adenoma or carcinoma (combined) in the lung." No discussion took place, so Dr. Eaton called for a motion. Dr. Andrews-Jones moved to accept the conclusion as written; Dr. Felter seconded. The vote was 11 yes, 0 no, so the motion carried.

Dr. Andrews-Jones moved to include hibernomas as *equivocal evidence of carcinogenicity*. Dr. Wyde delineated the incidence and stated none occurred in the historical controls. Dr. Harkema observed that the SAR was low in fat. Dr. Kuster clarified that the SAR might not be the correct unit of merit. For example, the induced E-fields in fat are similar to the E-fields induced in other tissues. Dr. Rinke asked where the hibernomas were located. Dr. Brix believed they were mesenteric but was not completely sure. Dr. Lin asked that tumor incidences be projected to aid memory, so that votes could be taken on quantitative data. Dr. Eaton said that was why staff were being asked to review the evidence in each instance. Dr. Lin was concerned that the conclusions were biased toward a linear-only response. Dr. Eaton disagreed with that assertion. Dr. Rinke pointed out a number of uncommon tumors had been observed, including teratomas and pituitary tumors. The panel examined the incidences of those tumors. Dr. Brix pointed out that the only tumor being discussed in the GSM males was the hibernomas. Dr. Eaton called for a second to the motion; there was no second, so the motion did not carry.

Dr. Felter noted that in some instances no tumors occurred in the treated animals but did occur in the sham controls. Dr. Eaton said that point was legitimate, but that the *equivocal evidence* conclusion would address the point. Dr. Malarkey pointed out that a vote for *equivocal* does not differentiate between linear or nonlinear responses.

GSM-Exposed Females

Dr. Eaton moved to the next conclusion, for GSM-exposed females, which was "*equivocal evidence of carcinogenic activity* based on incidences of malignant lymphoma (all organs)." Dr. Wyde described the incidences of malignant lymphomas and stated that, although all exposed groups were outside of the historical control range, no SAR-dependent increase in response occurred. He said that the sham control group was below the historical control range and all exposed groups were similar within the historical range, even those that were statistically significant. These together led to the *equivocal evidence* conclusion. Dr. Eaton noted the very low tumor incidence rate in the sham controls and that the historical control incidence was highly

variable; he expressed concern over whether this control was adequate due to such low background levels.

Dr. Eaton called for a motion. Dr. Andrews-Jones moved to accept the conclusion as written; Dr. Harkema seconded. The vote was 9 yes, 2 no, so the motion carried. Drs. Corcoran and Cline were the "no" votes. Dr. Corcoran explained his "no" vote as this is a unique case in which the historical controls might not be very informative and also cited the lack of linearity in dose response. He asked Dr. Brix why the call had not been *some evidence*. She explained that no abnormal pattern had been seen; all incidences were similar across exposure groups and all were within expectations. Dr. Cline explained that his "no" vote was based on the parallel control. He believed the response at the low- and mid-exposure groups was a real effect and was also confident in the statistics.

CDMA-Exposed Males

The panel next considered the CDMA modulation conclusions for the male mice. The call was "*equivocal evidence of carcinogenicity* based on incidences of hepatoblastoma of the liver." Dr. Wyde related the incidences and explained that no SAR-dependent increase and no positive trend were observed, and the sham control incidences were at the high end of the historical control range. Dr. Felter said the relevance of hepatoblastomas has changed over the years; therefore, the entire spectrum of liver tumors should be considered. Given the variability and high background incidence, she asked for clarification as to why the call was *equivocal evidence* and not *no evidence*. Dr. Brix said the call was made because the incidence in exposed groups was two-fold higher than in the sham controls. Dr. Harkema agreed that the *equivocal* call was the most conservative approach.

Dr. Eaton called for a motion on the conclusion. Dr. Andrews-Jones moved to accept the conclusion; Dr. Adler seconded. The vote was 10 yes, 1 no. The "no" vote was Dr. Felter. Dr. Felter reiterated the points she had made in the discussion to justify her "no" vote.

Dr. Andrews-Jones moved to add pituitary tumors in the mid-dose group as *equivocal evidence*, the incidence of which was two adenomas and one carcinoma, which were considered rare. There was no second, so the motion did not carry.

CDMA-Exposed Females

The panel proceeded to the conclusion for CDMA-exposed female mice. Dr. Wyde explained the incidence and rationale for the call, which was "*equivocal evidence of carcinogenic activity* based on incidences of malignant lymphomas (all organs)." Dr. Wyde stated that the incidences were statistically significant only at 2.5 W/kg, which differed from the GSM modulation. There was no discussion. Dr. Andrews-Jones moved to accept the conclusion as written; Dr. Felter seconded. The vote was 11 yes, 0 no, so the motion carried unanimously. There was no motion to add additional tumors.

Nonneoplastic Lesions

The panel moved on to consider the nonneoplastic lesions, which were GSM and CDMA combined. The conclusions were that neither modulation increased the incidence of nonneoplastic lesions in male or female mice. The panel discussed whether considering the modulations together was appropriate, based on the fact that the frequencies actually differed,

along with some other elements. Ultimately, they agreed the conclusion was acceptable when evaluating weight of evidence and biological relevance; however, the data should not be combined for statistical analysis. Dr. Eaton called for a motion to accept the conclusions as written. Dr. Adler so moved, and Dr. Felter seconded. The vote was 11 yes, 0 no, so the motion carried unanimously.

Final Conclusions

The final list of conclusions for the RFR studies in mice follows:

Technical Report TR 596: Cell Phone Radiofrequency Radiation Studies in Mice

<u>GSM Modulation</u>

Male B6C3F1/N mice, exposed to GSM-modulated cell phone RFR at 1,900 MHz

- Equivocal evidence of carcinogenic activity
    - Combined incidences of fibrosarcoma, sarcoma, or malignant fibrous histiocytoma in the skin
    - Incidences of alveolar/bronchiolar adenoma or carcinoma (combined) in the lung

Female B6C3F1/N mice, exposed to GSM-modulated cell phone RFR at 1,900 MHz

- Equivocal evidence of carcinogenic activity
    - Incidences of malignant lymphoma (all organs)

Exposure to GSM-modulated cell phone RFR at 1,900 MHz did not increase the incidence of any nonneoplastic lesions in male or female B6C3F1/N mice.

<u>CDMA Modulation</u>

Male B6C3F1/N mice, exposed to CDMA-modulated cell phone RFR at 1,900 MHz

- Equivocal evidence of carcinogenic activity
    - Incidences of hepatoblastoma of the liver

Female B6C3F1/N mice, exposed to CDMA-modulated cell phone RFR at 1,900 MHz

- Equivocal evidence of carcinogenic activity
    - Incidences of malignant lymphoma (all organs)

Exposure to CDMA-modulated cell phone RFR at 1,900 MHz did not increase the incidence of any nonneoplastic lesions in male or female B6C3F1/N mice.

Day 2 of the proceedings was adjourned at 4:31 p.m.

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