

Q2: Introduction

I am submitting this comment with my perspectives in response to the U.S. Department of Health and Human Services' Request for Information on Electromagnetic Fields (EMFs), Radiofrequency (RF) Radiation, and Wireless Radiation Exposure.

I am responding from several perspectives: as a software engineer with extensive experience working with technology and electronic systems; as a person who has experienced significant symptoms that I associate with exposure to electromagnetic fields and wireless radiation; and as a professional who has spent the past several years measuring and documenting electromagnetic field exposures in my home and other environments.

In January of 2022 I eliminated wireless technologies completely from my personal environment and whenever feasible reduced or distanced myself from electric and magnetic emissions. These changes improved my health and allowed me to reengage with the world. Unfortunately, avoidance of wireless technologies required changes that permanently affected my career, family, and personal life.

It is impossible to avoid being exposed to all wireless and electromagnetic emissions. Radio frequency exposures from sources which are not my own continue to aggravate my symptoms and limit my life. I don't want to feel these symptoms anymore when doing normal things like working in an office, walking into a store with an overpowered mesh / wifi system, going to a concert, restaurant, bar, or visiting family or friends.

Over the last few years, I learned more about detection, identification, measurement, and mitigation to electromagnetic emissions. My sister became a Building Biology Institute-certified Electromagnetic Radiation Specialist (EMRS). Together we develop practical methods for detecting, measuring, documenting, and reducing electromagnetic exposures. Using these strategies we have significantly improved my functionality and not only am I back at the computer, but I have developed a web application that shows electromagnetic emissions and measurement statistics spatially.

I have become particularly concerned that consumers are uninformed about the specifications of a product's wireless features and have limited or no control over those features. Technology will continue to develop faster than long-term health research and regulatory processes can reasonably keep pace with it. Additionally, the way RF exposure is evaluated does not always reflect the conditions people experience in their daily lives.

I therefore encourage HHS to consider these particularly practical areas for regulatory and technology standards:

1. **Wireless devices should provide a genuine, user-accessible means of turning off wireless emissions**, rather than merely hiding wireless functionality or placing a device into a mode in which emissions continue.

2. **Cellular phones should support calls and text messaging when the phone is connected through a wired Ethernet connection to a router**, so that consumers who choose a wired network connection can use their phones for these functions without requiring an active wireless connection.
3. Products should be required to display prominently on the packaging **standardized consumer-facing RF exposure information**, similar in concept to other standardized product information that allows consumers to compare products and make informed choices.
 - the type, number, frequencies and transmission characteristics of a device;
 - how to reduce unnecessary close-proximity exposure;
 - how to use wired alternatives where available;
 - how to disable wireless functions completely;
 - whether a device continues transmitting while in standby or charging;
 - whether simultaneous transmitters were evaluated;
 - whether children or other populations were specifically evaluated; and
 - what exposure conditions were and were not included in testing.

I am particularly concerned about exposure involving **children, infants, pregnancy, and other populations that may differ from those of a typical adult**. Children may spend many hours in schools and childcare facilities surrounded by multiple wireless transmitters, sometimes at very close distances. Wireless devices are also increasingly incorporated into products used by infants and children. Federal research and exposure assessment should therefore specifically address age-specific and developmental exposure scenarios rather than assuming that adult testing adequately represents all populations.

I also believe that federal research priorities should include **long-term, independent investigation of cumulative and chronic exposure**, children and pregnancy, reproductive and developmental outcomes, neurological and sleep-related effects, cardiovascular and other biological effects, environmental and ecological effects, and exposure associated with evolving technologies such as 5G, future wireless systems, IoT devices, wearables, smart homes, wireless medical devices, and increasingly dense wireless infrastructure. Research should be sufficiently broad to investigate questions that may have important public-health or regulatory implications, including questions that could ultimately lead to changes in technology standards or industry practices.

I believe that the federal government should consider existing scientific studies and partner with existing professionals and organizations to research the effects of EMF/RF in order to take pragmatic steps to inform and protect our environment and biological systems. Please consider my list of references in Q18 which has the reference associated with an FCC topic and the HHS question. Additionally, please consider other available resources of EMF/RF scientific studies. One example is the [EMF-Portal](#), which is an internet information platform of the RWTH Aachen University, that summarizes systematic scientific research data on the effects of electromagnetic fields (EMF). The core of the EMF-Portal is an extensive literature database with an inventory of 51,076 publications and 7,012 summaries of individual scientific studies on the effects of

electromagnetic fields. Another example is the [Curry et al. / Systematic Map \(2024\)](#) scientific study, which identified **334 relevant studies: 237 on fauna and 97 on flora**.

Q3: We invite individuals, families, caregivers, healthcare professionals, and organizations to share experiences regarding potential adverse health effects they believe may be associated with exposure to RF/EMFs.

Respondents are encouraged to provide as much detail as they are comfortable sharing, recognizing that responses to this RFI will be public and therefore should not include PII or PHI. Examples of information that may be helpful to include are the following:

Q3(a). The type(s) of wireless technology or RF/EMF source(s) involved (e.g., mobile phones, Wi-Fi, smart meters, wireless infrastructure, wearable devices, occupational equipment).

The types of wireless technology and RF/EMF sources that I have identified as affecting my symptoms include personal wireless devices and wireless infrastructure, electrical devices and appliances, and wires/power lines.

RF wireless sources include mobile phones, wireless printers, smart watches, Bluetooth devices and speakers, baby monitors, Wi-Fi routers and access points, smart televisions, wireless speakers, cameras, mesh-network equipment, smart meters, wireless security systems, smart thermostats and other connected home products, as well as wireless headphones and other wearable devices.

Electric and magnetic sources include lighting, ovens, HVAC systems, power supply and breaker box, and pool equipment. I have experienced symptoms in environments containing wireless and electronic equipment such as laptops, computers, printers, and other electrically powered equipment. In addition to radiofrequency (RF) sources, I have monitored electric and magnetic fields from electrical wiring, appliances, lighting, electrical service equipment, and other sources within my home and my clients homes.

Because multiple sources can be present simultaneously, I began using EMF measurement equipment to distinguish among RF, electric-field, and magnetic-field exposures rather than treating all electromagnetic exposure as a single category.

Q3(b) The nature, duration, frequency, and approximate timing of the reported exposure(s)

My response to exposure varies depending on the type, intensity, proximity, and duration of the exposure. I have observed that symptoms can begin very quickly after entering an environment with multiple active wireless devices. Distance from a source generally reduces the intensity of the symptoms, with the strongest effects occurring when I am close to a transmitting device.

For example, I have found that I can generally function for approximately four hours, although with moderate symptoms, in a highly connected environment where multiple people are using smartphones and other wireless devices. In contrast, when I am positioned between a transmitting smartphone and a Bluetooth speaker that is actively transmitting music, I have experienced noticeable symptoms within approximately five minutes.

After a significant exposure, symptoms can continue for many hours and, in some instances, approximately 24 hours or longer. The duration and intensity vary depending on the exposure and circumstances.

These observations have been consistent since approximately January 2022. Because I wanted to better understand the relationship between my symptoms and different environmental exposures, I began measuring electric, magnetic, and radiofrequency fields using EMF measurement instruments. I have continued to document exposures and my responses to different environments in an effort to identify patterns and reduce exposures that appear to aggravate my symptoms.

Q3(c): The potential adverse health effects experienced.

I have experienced a range of physical, neurological, sensory, and other symptoms that I associate with exposure to electromagnetic fields and wireless radiation. The intensity and duration of these symptoms vary depending on the environment and exposure. I began carefully monitoring both my symptoms and the electromagnetic environment because I wanted to understand the circumstances under which they became more or less severe.

The symptoms I have experienced include:

- Dizziness
- Nausea
- Chest pain or discomfort
- Heart palpitations
- Burning sensation in the lungs or chest
- Forgetfulness and difficulty concentrating or thinking clearly
- A sensation of heaviness in my head and heart
- Painful headaches, including stabbing and throbbing sensations
- Intermittent stabbing or painful sensations in different parts of my body
- Ice cold water trickling sensations in my head
- Burning and painful eyes
- Difficulty moving my face and hands
- A sensation of numbness in my head
- Loss of dexterity
- Episodes of passing out
- Episodes of loss or significant reduction of vision
- Tinnitus, at times painfully loud
- Insomnia and difficulty sleeping

- Tingling sensations in my feet, including during the night
- Abdominal discomfort, particularly when lying down at night
- Gas and gastrointestinal discomfort after meals

Some of these symptoms were severe enough to interfere with my ability to work, use computers, leave my home, socialize, and carry out normal daily activities. I have also experienced episodes in which several symptoms occurred together following substantial exposure.

I recognize that these symptoms can have many possible causes, but no specific medical diagnosis was determined through consultations with my primary care, cardiac, neurologic, and mental health practitioners. I am reporting them because I have observed recurring changes in their intensity and duration in connection with changes in my electromagnetic environment, including circumstances in which reducing exposure was followed by improvement.

Q3(d): When potential adverse health effects first appeared relative to when exposure began and whether any changes in exposure coincided with potential adverse health effects:

My symptoms first became significant in approximately January 2022. At that time, I was experiencing symptoms in environments with substantial exposure to wireless devices and other electromagnetic fields. I subsequently began paying close attention to the relationship between my symptoms and my electromagnetic environment.

I observed that symptoms could become more noticeable during or following exposure and that reducing exposure was followed by a reduction in the intensity or duration of some symptoms. These observations led me to begin measuring electromagnetic fields in my environment and tracking the circumstances surrounding my symptoms. I have continued doing this since 2022 because I wanted to better understand the patterns rather than relying solely on subjective impressions.

Q3(e): Whether medical evaluation or treatment was sought, including any diagnoses received (if the respondent chooses to share them).

I sought medical evaluation for my symptoms from my primary care physician, a cardiologist, a neurologist, and a mental health practitioner. The evaluations and testing did not identify a specific medical condition that explained the full range of symptoms I was experiencing.

I was encouraged by my primary care physician to consider antidepressant medication, but I did not believe and my therapist did not believe that depression or anxiety adequately described what I was experiencing. My symptoms appeared to vary with my physical environment and, in particular, with my exposure to electromagnetic fields and wireless devices.

I also consulted a holistic doctor and discussed my symptoms with practitioners who were familiar with electromagnetic hypersensitivity (EHS). In May of 2022, an Electromagnetic

Radiation Specialist (EMRS) performed an assessment of my home and provided recommendations for reducing sources of electromagnetic fields and electromagnetic radiation.

I also sought evaluation for recurring eye symptoms, including pain and episodes of cloudiness in my left eye. My eye doctor diagnosed inflammation inside the eye and treated it with steroids. During that evaluation, I also discussed episodes of temporary vision loss that I had experienced. I was informed that some of the symptoms could resemble those associated with vertebrobasilar artery insufficiency, although my episodes did not occur in connection with changes from sitting to standing.

I continue to monitor these symptoms and their relationship to my environment.

Q3(f): Whether steps to reduce or eliminate exposure were taken and, if so, whether any subsequent changes in potential adverse health effects were observed.

I took substantial steps to reduce or eliminate my exposure to electromagnetic fields and wireless radiation after experiencing persistent symptoms.

In May 2022, an Electromagnetic Radiation Specialist (EMRS), certified by the Building Biology Institute (BBI), evaluated my home and car and provided recommendations for reducing sources of electromagnetic fields and electromagnetic radiation.

I eliminated the use of wireless devices in my home, including Alexa devices, smart televisions, Bluetooth speakers, and other wireless equipment. I also changed the lighting in my home, powered down electronics when they were not needed. I changed my home environment to rely on wired rather than wireless technology.

After making these changes, I observed a significant improvement in my ability to function. Some symptoms improved quickly, while others became less intense or did not last as long. I continue to experience symptoms when exposed to RF and other electromagnetic sources.

My sister became certified as an EMRS by the Building Biology Institute, and together we developed additional strategies for identifying and reducing electromagnetic exposures. I continue to notice that exposure to Bluetooth, Wi-Fi, and cellular transmissions aggravate my symptoms including dizziness, pain, nausea, and tinnitus. I also continue to observe symptoms in response to elevated magnetic fields, such as those associated with electrical service equipment and breaker panels, and elevated electric fields associated with some household appliances and electrical devices.

I have not been able to eliminate electromagnetic exposures completely because I remain exposed to cellular infrastructure, including three nearby cellular antennas, wireless devices operated by neighbors, electrical service, utility smart meters, and ordinary appliances and electronics that are necessary for daily life. My experience has instead been that reducing exposure, where practical, has made a meaningful difference in the intensity and duration of symptoms and in my ability to function.

Q3(g) :Any supporting documentation, including scientific reports, exposure measurements, or other relevant information.

I have included examples of exposure measurements and summaries organized and statistics calculated using the Illuminate EMF program I developed with my sister, which documents electromagnetic field measurements in residential environments.

I am providing these examples because they illustrate how I currently document exposure conditions in actual residential environments: identifying the type of field being measured, recording the measurement location and conditions, preserving the underlying measurements, and using statistical summaries to describe the observed range and variability.

I believe this type of documentation can be useful for future research because it provides a structured way to associate measured environmental conditions with observations about when and where symptoms or other effects are reported.

A smart-home EMF survey in a residence containing at least one IoT or wireless device in each room included 206 measurement locations and 6,356 data points across RF, AC electric-field, and AC magnetic-field measurements, with an equal number of measurements for each category.

Measurements were made using a GQ EMF-390 Pro during a single approximately eight-hour survey period. At each location, measurements were recorded for approximately 30 seconds. The meter records approximately one reading per second, so the reported average at each location represents the arithmetic mean of approximately 30 readings, while the reported peak represents the maximum reading recorded during that interval. The instrument's RF measurement range is approximately 10 MHz to 10 GHz, with calibration specified around 2.4–2.5 GHz.

The survey was conducted while occupants were not actively using the home's wireless devices. Interior and perimeter measurements were collected within the same survey period, allowing comparison of RF conditions within occupied rooms with measurements around the perimeter of the residence. The instrument did not provide frequency-specific source identification, so individual RF readings cannot be attributed to a particular wireless device solely from the RF measurement.

In this home, AC magnetic fields remained low and relatively stable throughout nearly all interior locations. AC electric-field elevations were generally localized around energized electrical equipment, power strips, and plugged-in devices. RF was the most variable exposure category, with substantially higher measurements in several occupied rooms containing or located near wireless equipment.

The highest RF measurements included a peak of 371.794 mW/m² and an average of 232.134 mW/m² near the central Wi-Fi router. Other occupied areas showed lower but measurable RF

elevations, including an average of 12.658 mW/m² in one living area, 9.148 mW/m² in a workspace, 4.522 mW/m² in a sleeping space, and 0.767 mW/m² in the primary sleeping space.

Measurements in rooms adjacent to or vertically above or below areas containing concentrated wireless equipment demonstrated that measurable RF was distributed beyond the immediate location of an individual device. The interior measurements were consistently higher than perimeter measurements during this survey period, indicating that, in this particular home, internal wireless sources were an important contributor to the measured RF environment.

Controlled unplugging tests provided additional information about source contributions. In selected areas, removing wireless devices reduced the sustained RF baseline by approximately 20–35%. Unplugging electrical equipment reduced AC electric-field levels by approximately 45% in affected areas and by approximately 67% at the bed.

This survey represents a single measurement period rather than repeated measurements over multiple days or under different network conditions. Its value is as an example of how substantially the measured electromagnetic environment can vary from room to room within an occupied smart home and how multiple wireless and electrical sources can contribute to that environment.

Using a Safe and Sound RF meter to measure a baby monitor. measured RF emissions exceeded 500,000 $\mu\text{W}/\text{m}^2$ from the parent unit when the unit appeared to be off but remained plugged in for charging. The instrument's RF measurement range is approximately ~200 MHz –8 GHz, with calibration specified around ~1.8 GHz.

Televisions and other consumer electronics can similarly continue to communicate wirelessly or emit RF radiation when they appear to be turned off. Federal agencies should consider requiring clear disclosure of these operating states and a readily accessible method for completely disabling wireless transmissions.

I believe EMR Home Surveys of this type can complement standardized device testing by providing information about the actual electromagnetic environment experienced in occupied spaces. A more complete exposure-assessment framework should consider location, duration, multiple simultaneous sources, network activity, proximity, building configuration, and changes in exposure over time rather than relying solely on a single standardized measurement or device-specific exposure metric.

Q4(h): The types of potential adverse health effects reported.

As a professional who has spent the past several years measuring and documenting electromagnetic field exposures, my observations during residential electromagnetic field assessments and related discussions, is that individuals have reported a variety of symptoms that they associate with their electromagnetic environment. Reported symptoms have included:

- Skin rashes or skin irritation
- Tinnitus or ringing in the ears

- Difficulty sleeping or inability to sleep
- Nausea
- A sensation of the skin crawling or feeling like “fire ants”
- Pins-and-needles sensations or tingling

These reports come from individuals of different ages and backgrounds. I am reporting these as symptoms described by individuals during EMR home survey assessments or consultations and the relationship they perceived between their symptoms and EMF sources.

Q4(i): Onset of potential adverse health effects.

Clients have reported different patterns regarding the onset of their symptoms. Some reported that symptoms began or became noticeable after a new cellular tower was installed near their home. Others reported symptoms beginning or becoming noticeable while spending time in environments with new or elevated electric, magnetic, or radiofrequency fields.

Q4(j): Characteristics of the individuals or populations involved, excluding any identifying information such as PII or PHI.

The clients reporting these symptoms have included both adult males and adult females, as well as children and adolescents. Reports have included toddlers, preschool-aged children, teenagers, and young adults, in addition to older adults.

The individuals were encountered in the context of residential electromagnetic field assessments and related consultations.

Q4(k): Any observed exposure patterns.

During residential assessments, I have observed that individuals reporting particular symptoms sometimes also had elevated measurements of one or more types of electromagnetic fields. The measurements and reported symptoms varied substantially between individuals and environments.

Examples of exposure patterns observed during assessments include:

- Individuals reporting difficulty sleeping who had measured nighttime exposures including approximately 3,000–5,000 mV body voltage at rest, 1–5 mG magnetic fields, 30+ degrees of static magnetic deviation as measured on their mattress. 10–100 V/m electric fields, and 100–500,000 $\mu\text{W}/\text{m}^2$ radiofrequency fields.
- Individuals reporting numbness, tingling, or nausea who had measured electric fields in the range of approximately 10–100 V/m and radiofrequency fields ranging from approximately 100 to 3.1 million $\mu\text{W}/\text{m}^2$.
- Individuals reporting skin rashes who had measured radiofrequency exposure ranging from approximately 500,000 to 3.1 million $\mu\text{W}/\text{m}^2$, including situations involving proximity to cellular antennas and personal wireless devices.

These observations are based on measurements taken during individual residential assessments and the symptoms reported to be associated with electromagnetic emissions by the individuals. Exposure conditions can vary substantially over time and by location, and multiple sources may be present simultaneously.

I believe these observations illustrate the value of identifying and quantifying multiple types of electromagnetic exposure rather than relying on a single measurement or source. In my experience, understanding the environment may require repeated measurements, identification of different sources, and consideration of changes that can be made to reduce exposure where practical.

Q4(l):What standardized methods were used to assess exposure or potential adverse health effects, if any were used.

For residential assessments, I use electromagnetic field measurement instruments to separately evaluate radiofrequency (RF), AC electric fields, AC magnetic fields, AC current, and, where appropriate, body voltage and static magnetic fields. Measurements may be taken at specific locations as individual readings or logged over time to document changes in exposure.

I use the Illuminate EMF Tool, powered by the Pettit Profile framework, to organize measurement data, identify measurement locations and field types, preserve the underlying measurements, and generate structured reports. The tool can incorporate both manually collected measurements and logged data from compatible measurement instruments.

The purpose of this process is to consistently identify and quantify electromagnetic field conditions in a particular environment. It is not a clinical diagnostic method and is not intended to establish that a measured exposure caused a reported health effect.

In my experience, documenting the exposure conditions separately and over time can provide useful information for evaluating an individual's environment and for identifying practical opportunities to reduce exposure where appropriate.

Q4(m): Recommendations for future research or surveillance.

I believe additional research would be useful to better understand reported health effects in relation to real-world electromagnetic field and radiofrequency exposure. I also believe it is important to build on research that has already been conducted rather than treating these subjects as entirely unexplored.

See the resource list in Q18 for studies where research has already begun, and where additional well-designed and independently replicated studies would be valuable to include:

- **Neurological and developmental effects**, including research concerning RF/EMF exposure and neurological health, neurodevelopment, and potential effects during pregnancy and other developmental periods.

- **Voltage-gated calcium channels and cellular signaling**, including research examining proposed effects of electromagnetic fields on calcium signaling and related biological pathways.
- **Oxidative stress and related biological markers**, including research examining oxidative-stress, inflammatory, and other biomarkers in individuals reporting sensitivity or adverse effects associated with electromagnetic exposure. Published studies have investigated biomarkers such as lipid peroxidation products, glutathione-related measures, nitrotyrosine, and antioxidant enzymes in individuals reporting electrohypersensitivity.
- **Clinical characterization of individuals reporting electromagnetic sensitivity**, including research to better characterize symptom patterns, potential biomarkers, clinical presentation, and possible subgroups. There is already published clinical and review literature addressing these questions, although the interpretation of that evidence remains contested.
- **Human case studies and longitudinal observations**, particularly studies that combine detailed exposure measurements with information about symptoms, timing, duration, and changes in the individual's environment.
- **Exposure-reduction and mitigation approaches**, including research into practical interventions and methods for reducing exposure in residential and occupational environments.
- **Grounding, body voltage, and electric-field exposure**, including further research into how grounding and electrical characteristics of the built environment affect measured body voltage and current.
- **Standardized environmental exposure assessment**, so that measurements collected by different investigators can be compared more consistently and exposure conditions can be related to reported symptoms over time.

I believe research would be particularly valuable when it combines these approaches rather than examining only one factor in isolation. Individuals may encounter multiple sources simultaneously, including cellular signals, Wi-Fi, Bluetooth, electrical fields, magnetic fields, and other environmental exposures. Exposure can also vary substantially by location, distance, device activity, time of day, and duration.

I recommend that future studies collect detailed exposure measurements alongside individual symptom histories, including when symptoms begin, how long they last, what sources are present, and whether changes in the electromagnetic environment are followed by changes in reported symptoms. Longitudinal studies could be particularly useful because a single point-in-time measurement may not adequately characterize an individual's actual exposure.

I also believe there is value in developing standardized methods that allow individuals, healthcare professionals, researchers, and public health agencies to better identify and quantify environmental exposures. People who report symptoms associated with their environment should have access to understandable information about how exposures can be identified, measured, and, where appropriate, reduced.

Q5: What existing national and international exposure standards, guidelines, or regulatory frameworks should federal health agencies consider when evaluating the potential adverse health effects of human exposure to RF/EMF?

Q5(n): What scientific, technical, or regulatory changes by federal health agencies, if any, would improve the assessment, disclosure, and regulation of wireless radiation exposure?

Wireless devices should have a genuine, user-accessible means of turning off wireless transmissions, rather than simply hiding the wireless function from the user interface or putting the device into a mode in which the user assumes it is no longer transmitting. This distinction is important because some electronic products can continue to emit RF radiation even when they appear to be turned off.

Consumers should also be provided with clear information about the RF-emitting functions of electronic products, including whether emissions continue when a product is powered off, in standby mode, or charging; which wireless technologies are active; and how a consumer can completely disable those functions.

Another practical change would be to support wired connectivity for functions that currently depend on Wi-Fi or cellular wireless communication. For example, cellular phones should be capable of supporting calls and text messaging when connected through a wired Ethernet connection to a home router or other wired network. Wired networking is already supported for many other types of devices, yet cellular phones generally work on WiFi connections but do not provide an equivalent wired mode for these basic communications functions.

Providing consumers with meaningful wired alternatives would allow people to reduce their wireless exposure without having to give up important communication capabilities. It would also provide a practical exposure-reduction option for individuals who choose to minimize wireless radiation in their homes.

More generally, federal agencies should consider requiring standardized RF-emission disclosure that allows consumers, researchers, and health professionals to understand the actual operating characteristics of wireless products and compare exposure under realistic conditions rather than relying solely on manufacturer-described intended use. Federal agencies should improve RF/EMF exposure assessment by requiring greater transparency regarding the actual emissions and exposure characteristics of wireless products and infrastructure.

Exposure information should not be limited to a single SAR value or a laboratory measurement under a standardized configuration. Consumers and regulators should be able to determine, where technically feasible, the operating frequency, maximum and typical power or power density, modulation characteristics, duty cycle, pulsing characteristics, proximity assumptions, simultaneous transmission conditions, and other factors relevant to exposure.

Q5(o): Is additional research needed to develop, test, and evaluate the effectiveness of procedures and techniques for minimizing exposure to electronic product radiation? Where are the largest gaps, if any, in knowledge? What research is needed to appropriately evaluate current or future national and international exposure standards, guidelines, or regulatory frameworks.

Additional research is warranted in several areas:

- long-term and cumulative exposure;
- exposure below current federal limits;
- children and developing tissues;
- prenatal and early-life exposure;
- reproductive effects;
- simultaneous exposure to multiple RF sources;
- real-world exposure from Wi-Fi, cellular networks, wearables, IoT and smart-home devices;
- modulation, pulsing and duty-cycle effects;
- localized exposure from devices worn or carried close to the body;
- improved individual exposure assessment;
- biological effects that may occur without measurable tissue heating; and
- environmental and wildlife effects.

The National Toxicology Program studies are particularly important because they provide a large government-sponsored experimental dataset involving long-term exposure to cell-phone-type RF radiation.

Human experimental research should also remain part of the research agenda. Volkow et al. demonstrated that a 50-minute cell-phone exposure produced a measurable regional change in brain glucose metabolism in healthy adults, although the clinical significance of that finding remains unknown.

Additional research is needed, particularly research that evaluates exposure under realistic conditions of cumulative, prolonged, and simultaneous exposure.

One important gap is the assessment of cumulative exposure from multiple external and internal sources. People are rarely exposed to a single wireless source in isolation. A person may simultaneously be exposed to cellular infrastructure, Wi-Fi networks, Bluetooth devices, cordless devices, smart-home equipment, wireless appliances, and other RF sources. Exposure may also occur continuously or intermittently over many hours each day and over many years.

Research should therefore evaluate exposure patterns that more closely reflect real-world environments, including homes, schools, workplaces, childcare settings, and outdoor areas near wireless infrastructure. This should include simultaneous exposure to multiple frequencies and sources, as well as variations in modulation, pulsing, duty cycle, distance, and duration.

Particular attention should be given to exposure from external cellular and wireless infrastructure. As cellular towers and other wireless infrastructure are installed in or near residential communities and locations where children live and learn, it is important to characterize actual environmental exposure rather than relying only on theoretical or modeled exposures.

Q5(p): How, if at all, should a classification system account for exposure-related characteristics, including operating frequency, power density, specific absorption rate (SAR), electric- and magnetic-field strength, modulation and pulse characteristics, duty cycle, beamforming, simultaneous exposure to multiple frequencies, duration of exposure, distance from the source, proximity to the body, and cumulative exposure over time?

A classification system should account for multiple exposure-related characteristics rather than relying on a single measurement such as SAR or power density.

At a minimum, an exposure classification framework should consider:

- **Operating frequency**, because different frequencies have different propagation characteristics and interact differently with the body.
 - **Power density and electric- and magnetic-field strength**, particularly for environmental and far-field exposures where these measurements can provide information about the actual exposure present at a location.
 - **Specific absorption rate (SAR)** for exposures in which the source is sufficiently close to the body for localized energy absorption to be relevant. SAR should not, however, be treated as a complete characterization of environmental RF exposure.
 - **Modulation and pulse characteristics**, because two signals with similar average power can have substantially different temporal characteristics.
 - **Duty cycle**, including the proportion of time a transmitter is actively transmitting.
 - **Beamforming and other directional transmission characteristics**, which can affect where and how exposure is distributed in the environment.
 - **Simultaneous exposure to multiple frequencies and sources**, rather than evaluating each source independently when people are actually exposed to them concurrently.
 - **Duration of exposure**, including both individual exposure events and repeated exposure over days, months, and years.
 - **Distance from the source and proximity to the body**, because exposure characteristics can change substantially with distance and because near-field and far-field conditions are not equivalent.
 - **Cumulative exposure over time**, including exposure from multiple sources and technologies.
- Diversified age and body characteristics** to represent every person's actual exposure and biological dose.

A useful classification system should preserve these characteristics rather than reducing them prematurely to a single composite number.

The classification system should also distinguish between exposure that is intentionally generated by a device being used and exposure that occurs unintentionally or without the consumer's awareness, such as emissions during standby, charging, background communication, or operation of nearby infrastructure.

Finally, exposure assessment should include actual measured environmental conditions where feasible. Modeling and manufacturer specifications are useful, but measurements can reveal the contribution of multiple sources, temporal variation, and operating states that may not be apparent from a device's primary advertised function.

A multidimensional approach would provide federal health agencies with a more complete framework for comparing existing and emerging wireless technologies and for identifying where additional research is needed.

Q6. What scientific evidence exists about potential adverse health effects caused by current exposure limits?

There is a substantial body of scientific literature investigating biological and potential health effects associated with radiofrequency electromagnetic field (RF-EMF) exposure. This literature includes human studies, occupational and environmental studies, animal research, and laboratory research examining biological mechanisms. Please see the additional references in Q18.

The National Toxicology Program conducted long-term whole-body studies of cell-phone-type RF radiation in rats and mice. In the 900 MHz GSM/CDMA rat study, the NTP reported clear evidence of carcinogenic activity in male rats based on malignant heart schwannomas, together with additional findings involving brain gliomas and adrenal tumors.

NTP TR-595 — Toxicology and Carcinogenesis Studies of 900 MHz GSM/CDMA RF Radiation

In the randomized crossover study by Volkow et al., 47 healthy adults underwent 50 minutes of cellular-phone exposure, and regional brain glucose metabolism increased in areas closest to the antenna.

Volkow et al., JAMA — Effects of Cell Phone Radiofrequency Signal Exposure on Brain Glucose Metabolism

A systematic review and meta-analysis by Adams et al. found reduced sperm motility in pooled human studies of mobile-phone exposure.

Adams et al., Environment International — Mobile phones and sperm quality

The International Agency for Research on Cancer (IARC), part of the World Health Organization, classified radiofrequency electromagnetic fields as Group 2B, “possibly carcinogenic to humans,” in 2011.

Taken together, these findings indicate that the scientific question extends beyond whether exposure produces immediate measurable heating and should include long-term, reproductive, developmental, neurological and other biological endpoints including:

- **Human and occupational research**, including studies examining cancer, leukemia, reproductive outcomes, neurological effects, sleep, and other health endpoints.
- **Animal research**, including studies examining cancer, reproductive and developmental effects, neurological outcomes, oxidative stress, endocrine effects, and other biological changes.
- **Laboratory and mechanistic research**, including studies of oxidative activity, calcium signaling, gene expression, cellular responses, blood-brain-barrier permeability, and other biological processes.
- **Research involving children and developmental exposure**, which raises questions about whether exposure assessment and dosimetry should adequately account for age, anatomy, development, behavior, and duration of exposure.
- **Research involving cumulative and real-world exposure**, including exposure from multiple simultaneous sources, proximity to transmitting devices, duration, modulation, pulsing, duty cycle, and changing environmental conditions.

In my view, these areas of research are important when evaluating whether the existing regulatory framework fully represents the exposures experienced by the public today. A person may experience RF exposure from a cellular phone, Wi-Fi access points, Bluetooth devices, wearables, smart-home equipment, cellular infrastructure, and other sources simultaneously and repeatedly over many hours. A device-specific compliance measurement does not necessarily characterize that cumulative environmental exposure.

The evidence concerning reported effects **below** current federal exposure limits is addressed separately in Question 12, where I provide specific examples from the scientific literature.

Q7: What scientific methods are currently available for accurately characterizing individual and population-level RF radiation exposure?

There are several established scientific and technical methods for characterizing RF radiation exposure, including specific absorption rate (SAR) measurements and computational modeling, electric-field and magnetic-field measurements, power-density measurements, broadband and frequency-selective RF measurements, personal exposure dosimeters, fixed environmental monitoring stations, and numerical exposure modeling.

A significant limitation of the current approach is that SAR is often used as the principal metric for evaluating exposure from wireless devices used close to the body, while SAR does not

directly characterize the total RF environment experienced by an individual over the course of a day, week, or year.

The distinction between **compliance with an exposure limit** and **complete characterization of real-world exposure** is important. Current limits can provide a regulatory benchmark, but additional questions remain regarding long-term cumulative exposure, multiple simultaneous sources, close-proximity exposure, children and developing populations, and exposure patterns associated with newer wireless technologies.

I believe federal agencies should continue evaluating whether the scientific basis of current limits adequately reflects these conditions and should consider evidence from epidemiology, toxicology, animal research, mechanistic studies, exposure science, and actual environmental measurements together.

Q8: What, if any, improvements in exposure assessment methodologies are needed to better evaluate real-world exposure conditions?

A more complete exposure assessment should combine several measurement approaches.

Individual exposure

Individual exposure can be characterized using personal RF dosimeters or other wearable or portable measurement instruments that record RF exposure over time. These measurements can provide information about the actual exposure experienced by a person as they move through their home, workplace, school, vehicle, and outdoor environments.

Measurements should ideally record not only overall RF levels but, where technically feasible, information about frequency bands, time, duration, and temporal variation. This would help distinguish between continuous background exposure and intermittent exposure from individual transmitting devices.

Environmental exposure

Environmental exposure can be measured using calibrated broadband RF meters, frequency-selective instruments, spectrum analyzers, fixed monitoring stations, and validated field-strength or power-density measurements.

These measurements can characterize exposure in homes, schools, workplaces, public spaces, and areas surrounding cellular infrastructure. Fixed monitoring can also establish how exposure changes over time rather than relying on a single measurement made at one point in time.

Near-field exposure

In the near field, the relationship between electric field, magnetic field, and power density can be more complicated than under ideal far-field conditions. Reflections and other environmental factors can also produce substantial spatial and temporal variation.

Technical literature reviewed by IARC notes that far-field assumptions may not apply close to RF sources and that near-field exposure can require spatial scanning or dosimetric approaches rather than relying on a simple power-density calculation.

This is particularly relevant for devices used directly against or very close to the body, such as cellular phones, wearable devices, wireless headsets, and other portable transmitters.

Population-level exposure

At the population level, exposure should not be estimated solely from device certification data. A meaningful population exposure assessment should combine:

- measurements from representative homes, schools, workplaces, and public locations;
- personal dosimetry across representative populations and daily activities;
- measurements around cellular towers and other fixed wireless infrastructure;
- information about the number and type of transmitting devices in use;
- frequency-specific measurements;
- time-dependent measurements;
- geographic information and distance from transmitting infrastructure; and
- validated exposure models that can estimate exposure where direct measurement is impractical.

Repeated measurements over time would also be important because RF exposure is dynamic. A single location measurement may not represent the exposure experienced at the same location at another time of day or under different network conditions.

Federal health agencies should consider developing a standardized, reproducible framework for measuring, reporting, and analyzing **real-world RF exposure over time**, in addition to existing device-specific SAR testing. This is an area that the existing professional Building Biologists and certified EMRS professionals should be engaged by federal agencies as partners to obtain real world evidence.

Improve measurement of cellular infrastructure

Cellular towers and other fixed wireless infrastructure should have embedded emission/transmission warning or alert management systems that address emissions that are found to be out of expected ranges. These systems should be required to notify federal reporting systems. The Federal reporting systems should be responsible to monitor systematic issues, ensure faulty systems are corrected, and with transparency ensure the public is aware of these incidents.

These systems and public transparency is particularly important when infrastructure is located near homes, schools, childcare facilities, and other places where people spend significant amounts of time.

Connect exposure measurements to health research

Perhaps most importantly, exposure assessment should be designed so that the exposure measurements collected in health studies correspond to the exposure conditions actually experienced by participants.

Research should therefore collect sufficiently detailed exposure information to evaluate questions such as:

- How long was the individual exposed?
- What sources contributed to the exposure?
- Which frequencies were involved?
- Was exposure continuous or intermittent?
- Were multiple sources present simultaneously?
- How close were the sources to the body?
- How did exposure vary during the day?
- What was the cumulative exposure over the study period?

Q9: What, if any, technical and exposure-related information should be disclosed to consumers, residents, workers, schools, healthcare providers, and local governments?

Consumers and other members of the public should have access to clear, standardized, and comparable information about the RF emissions produced by wireless products and the RF exposure present in their environments. Additionally, as described in Q8, the public should be informed of anomalies where emissions from infrastructure are found to be faulty especially when the fault caused the system to emit higher than permitted emissions.

For products, a useful disclosure model would be a standardized **RF exposure information label**, similar in concept to the Nutrition Facts label found on food products. The purpose would be to provide consistent technical information that allows users to understand the product's wireless capabilities, compare products, and make informed decisions about how and where they use them.

Currently, consumers often have difficulty determining what wireless technologies a product contains, whether it continues transmitting when apparently turned off or placed in standby, how frequently it transmits, or what its maximum and typical RF emission characteristics are. Information may be available in technical documentation, but it is not generally presented in a standardized format that an ordinary consumer can readily compare across products.

Another reason I believe greater transparency is needed is that manufacturers themselves recognize that the distance between a wireless device and the user's body affects RF exposure. For example, Apple's RF exposure documentation states that iPhone SAR testing simulates use directly against the head with no separation, while body-worn testing uses a specified separation distance. Apple also recommends using hands-free options to reduce RF exposure. Earlier Apple product documentation specifically instructed users to keep the iPhone at least 15 mm (5/8 inch) away from the body during voice calls or cellular data use and stated that increasing distance reduces exposure. Samsung similarly provides body-worn separation requirements for its phones and recommends speaker mode or a headset to place more distance between the phone and the user's head.

I cite these manufacturer instructions as evidence that cellphone RF exposure details demonstrate an important transparency issue: the exposure represented by a device's compliance measurement depends on the conditions under which the device is tested and used. A consumer may reasonably understand that a phone "meets the RF exposure limits" without realizing that the testing involves specified distances, body locations, operating conditions, and assumptions about how the device is used.

I believe consumers should therefore be given clear, prominent information about these conditions. If a manufacturer recommends maintaining a particular separation distance to reduce RF exposure, that information should be readily visible to consumers rather than buried in regulatory documentation. Consumers should be able to understand the difference between a device's maximum or certified exposure under a specified test condition and the exposure that may occur during different patterns of actual use, including holding the phone against the head, carrying it against the body, using speakerphone, using a wired headset, or keeping the device at a greater distance.

A standardized RF information label

I believe that standard RF information labels should include a **box/front facing disclosure** as well as a **detailed full disclosure** within the packaging. The most important feature of any disclosure system would be **standardization**. A standardized RF disclosure system would improve transparency in much the same way that standardized nutritional labeling allows consumers to compare food products.

A consumer should not have to understand telecommunications engineering to determine whether one environment or wireless product has different RF emission characteristics from another. Measurements should use consistent units, terminology, test conditions, and reporting methods.

A standardized **box/front-facing disclosure** should be understandable to a typical consumer using non technical jargon to include:

- wireless technologies present in the device, such as cellular, Wi-Fi, Bluetooth, or other RF transmitters;

- standardized exposure classification
- whether a product transmits RF when it is:
 - actively being used;
 - connected but not actively being used;
 - in standby mode;
 - powered off;
 - charging;
 - connected to a wireless network in the background; or
 - performing automatic updates or other background communications.
- whether wireless functions can be completely disabled by the user;
- information about wired alternatives, if available.

The **full disclosure** within the packaging should include:

- operating frequency ranges;
- maximum transmitting power;
- maximum and representative SAR values for devices used close to the body;
- typical or representative transmitting power under specified conditions;
- duty cycle or transmission activity;
- modulation and other relevant signal characteristics;
- applicable electric-field or power-density measurements for environmental exposure;
- the measurement distance and conditions under which the measurements were obtained;
- whether multiple transmitters can operate simultaneously;
- the location of antennas and transmitters within the device;
- whether the device automatically increases transmission power under particular conditions

The disclosure should clearly identify what was and was not evaluated. For example, it should state whether testing was performed using adult standardized models only; whether child-specific or age-specific models were used; whether use in close proximity to the body was evaluated; whether prolonged or continuous operation was evaluated; whether simultaneous operation of multiple transmitters was evaluated; and whether realistic environments such as homes, schools, daycares, or other child-care settings were considered.

Information about actual exposure

For fixed wireless infrastructure, consumers and communities should have access to information about the RF environment created by cellular towers, antennas, wireless installations, and other significant RF sources. This system should include management systems connected between the cellular/satellite and other infrastructure RF producers to Federal Management Systems that provide transparent status and notifications to the public that include:

- operating frequencies;
- antenna locations and heights;

- transmitter power;
- antenna orientation and coverage;
- applicable beamforming characteristics;
- measured or modeled RF field strength or power density at representative locations;
- distance from residences, schools, childcare facilities, workplaces, and other occupied locations;
- changes in infrastructure that could materially alter exposure; and
- the methodology used to calculate or measure the reported exposure.

Actual environmental measurements should be distinguished from theoretical or modeled estimates.

Information for schools and childcare settings

Schools and childcare facilities should publish an inventory of wireless transmitting equipment and information about where those devices and antennas are located. Schools should be required to review this to ensure exposure to children is limited. For example, this information could be considered when placing desks, so that no child is located in the seats closest to transmitting devices including Wi-Fi access points, wireless classroom equipment, Bluetooth devices, cellular infrastructure located on or near the property, and other significant RF sources.

Q10: What data sources or surveillance systems currently exist to monitor potential adverse health effects associated with RF radiation exposure? Should additional data sources or surveillance systems be developed? Please discuss the benefits and challenges of the following data sources and surveillance systems, as relevant:

I am aware of public resources such as AntennaSearch (<https://www.antennasearch.com>), which provides searchable information on the locations and reported details of towers and antennas. I use this resource to identify potential wireless infrastructure near locations of interest.

I recommend that HHS identify and evaluate existing federal, state, academic, occupational, and environmental data sources; determine how well they capture exposure and health information; and identify gaps in coverage, standardization, accessibility, and long-term follow-up. Where existing systems are insufficient, a coordinated surveillance program could be developed to collect comparable exposure data and investigate potential health patterns, while protecting personal privacy and distinguishing reported symptoms, diagnosed conditions, measured exposure, and demonstrated causal relationships.

A stronger surveillance system would link standardized RF exposure information with health outcomes over time while maintaining appropriate privacy protections. This would make it possible to evaluate both individual and population-level patterns.

a. Disease registries

Existing disease registries, including cancer registries and registries for other chronic diseases, provide an important source of population-level health information. Disease registries could be strengthened by linking appropriate health data with standardized environmental and occupational RF exposure information while maintaining privacy protections.

b. Occupational monitoring

Occupational monitoring is particularly important for workers who may have substantially greater or more consistent exposure to RF sources than the general population. I believe that given the expansion of RF emitting products and IoT devices, schools, hospitals, daycares, nursing homes, and other sites that serve developing and compromised people should be monitored.

c. Environmental monitoring

Environmental RF monitoring is an important component of human, animal and insect population-level surveillance.

Measurements could be collected around cellular infrastructure, residential areas, schools, workplaces, and other locations where people, endangered species, pollinators, birds, trees, insects and other biological systems need to coexist.

d. Longitudinal cohort studies

Longitudinal cohort studies are one of the most valuable approaches for investigating potential long-term health effects.

Participants could have their health followed over many years while exposure information is collected using standardized environmental measurements, personal dosimetry, occupational information, residential history, and wireless-device use.

e. Biomonitoring

Biomonitoring could potentially provide information about biological responses associated with RF exposure. Research should investigate biomarkers involving oxidative stress, inflammatory pathways, endocrine responses, cellular signaling, neurological function, reproductive function, or other biological processes.

f. Adverse event reporting

A standardized system for reporting suspected adverse health events associated with RF-emitting products could provide useful information, particularly for identifying unexpected or emerging patterns. Consumers, healthcare providers, workers, and manufacturers could

potentially report symptoms or health events associated temporally with particular devices or exposure circumstances.

A standardized reporting system could be useful as an early-warning and hypothesis-generating mechanism if reports include sufficient information about the device, exposure circumstances, duration, frequency, and other relevant factors.

g. Disease or illness clusters

Investigation of disease or illness clusters will be useful when an unusual concentration of cases occurs in a location where there is a potentially relevant common exposure.

For example, if a community, workplace, or school reports an unusual pattern of a particular disease or symptoms following the installation or substantial modification of RF infrastructure, the situation could warrant systematic investigation.

When clusters are investigated, RF measurements should be conducted using standardized methods and, where possible, historical exposure should also be reconstructed.

h. Other

A particularly useful additional system would be a **national RF exposure surveillance database** that combines standardized environmental measurements with relevant health surveillance data while protecting individual privacy.

Such a system could incorporate:

- environmental RF measurements;
- personal dosimetry data from voluntary participants;
- occupational exposure measurements;
- locations and characteristics of major RF infrastructure;
- frequency-specific exposure information;
- exposure duration and temporal variation;
- residential and occupational history where appropriate;
- disease registry information;
- adverse-event reports;
- information from longitudinal cohort studies; and
- other validated exposure measurements.

I would also encourage federal health agencies to consider the existing workforce of trained and certified EMF measurement professionals, including Electromagnetic Radiation Specialists (EMRS) and Building Biology professionals, as a potential source of standardized environmental exposure data. There are professionals across the country who routinely conduct residential, commercial, workplace, and other environmental EMF assessments and who are motivated to collect accurate measurements and document sources, locations, and conditions.

Rather than requiring the federal government to create an entirely new field-measurement workforce, federal agencies could establish standardized measurement protocols, minimum equipment and calibration requirements, data-quality requirements, reporting formats, and a secure national data repository through which qualified professionals could voluntarily submit standardized measurements.

A national database could capture information such as measurement location and environment, date and time, instrument and calibration information, frequency range, measurement type, field strength or power density, measurement duration, source characteristics when identifiable, distance from sources, building characteristics, wireless technologies present, number and type of transmitters, and relevant environmental conditions. The database could also distinguish between spot measurements, repeated measurements, personal dosimetry, and longer-term monitoring.

Such a system could create a much larger and geographically diverse body of real-world exposure data than could reasonably be collected through federally funded research projects alone. It could also provide researchers with data from homes, schools, childcare facilities, workplaces, healthcare environments, and other locations that may otherwise be underrepresented in research datasets.

Importantly, participation should not mean that every submitted measurement is automatically treated as research-grade evidence. The system could incorporate quality-control procedures, standardized metadata, instrument requirements, calibration documentation, duplicate or validation measurements, and quality classifications so that researchers can determine which data are appropriate for particular analyses.

The resulting database could be used to characterize exposure patterns, identify geographic or environmental trends, improve exposure models, compare real-world environments, identify gaps in existing research, and generate hypotheses for further study. It could also provide an empirical foundation for evaluating whether current exposure-assessment methods adequately represent the environments in which people actually live and work.

I believe this approach could be particularly valuable because it would turn many otherwise isolated environmental measurements into a structured, potentially useful scientific resource. With appropriate safeguards for privacy and data quality, measurements collected by qualified field professionals could contribute to a national understanding of real-world EMF exposure and support both existing research and the development of new research questions.

Q11. Should exposure assessment or risk evaluation differ for sensitive populations such as those noted below? Please explain.

Exposure assessment and risk evaluation should distinguish children and pregnant women from the general adult population. The scientific evidence indicates that body size, anatomy, developmental stage, tissue characteristics or exposure patterns may alter absorbed dose or potential biological effects.

Children warrant particular attention because they have smaller bodies, developing tissues and potentially many decades of future exposure. Morris et al. reported that children can absorb higher doses of RF radiation from mobile phones than adults under comparable conditions.

Morgan et al. similarly examined the anatomical and dosimetric reasons why children may absorb more microwave radiation than adults.

The prenatal and developmental literature in the materials submitted with this response also includes studies examining prenatal exposure to Wi-Fi and cellular-frequency RF radiation and outcomes involving oxidative stress, neuronal development, behavior, fetal development and reproductive effects.

The combination of differences in absorbed dose, developmental vulnerability and the potential duration of exposure supports conducting specific risk assessment for children and pregnancy rather than assuming that results obtained from adult exposures necessarily provide complete protection for developing populations.

I therefore recommend that federal agencies prioritize:

1. child-specific dosimetry;
2. prenatal and fetal exposure assessment;
3. long-term developmental studies;
4. longitudinal studies beginning during pregnancy or childhood;
5. realistic assessment of exposure from multiple wireless sources; and
6. research into whether exposure reduction can reduce measurable biological effects.

Q11(a). Children

Children should receive specific consideration in RF exposure assessment and research. They differ from adults in body size, anatomy, physiology, development, behavior, and patterns of device use, and they may experience many more years of cumulative exposure.

The wireless environment surrounding children has also changed substantially. Wireless products are increasingly incorporated into products and environments specifically intended for infants and children, including baby monitors, infant sleep monitors and alerts, diaper-wetting alerts, connected swings and bassinets, Bluetooth-enabled toys and mobiles, location and tracking devices, connected shoes and bags, tablets, phones, watches, and other wearable or connected products. Some of these devices may operate close to the child's body for extended periods, including during sleep.

I believe the exposure assessment of children should therefore extend beyond the SAR characteristics of an individual device. It should examine the child's **actual exposure environment**, including the number and type of wireless devices present, their distance from the child, how long they transmit, and whether multiple sources operate simultaneously and assess the participants for biomarkers involving oxidative stress, inflammatory pathways,

endocrine responses, cellular signaling, neurological function, reproductive function, learning development, social integration, and other biological processes.

This is particularly important in schools, daycares, preschools, and other environments where children may spend many hours each day. Wireless access points or other transmitting devices near a child's seating should be a focus. For example, a child seated immediately adjacent to a transmitting device may experience a substantially different exposure than a child elsewhere in the room. Exposure assessments should therefore consider spatial variation within the room rather than treating the entire classroom or daycare as having a single representative exposure level.

I also believe the assessment should account for the broader electromagnetic environment. RF exposure is only one component of the overall electromagnetic environment in a school or daycare. Electric and magnetic fields from electrical wiring, power supplies, appliances, equipment, lighting, HVAC, computers, and other sources can contribute to a child's overall exposure and should be characterized separately rather than assuming that RF measurements alone describe the entire environment.

The principle I would recommend for children is **exposure minimization where reasonably practicable**, particularly in environments in which children have little ability to choose or control the sources to which they are exposed. This is similar in concept to other public-health approaches in which unnecessary exposure is reduced even when the evidence does not establish that every exposure produces harm. The relevant principle is that children's environments deserve a higher degree of preventive consideration when exposure can be reduced without impairing the essential function of the environment.

For schools and daycares, I would therefore recommend that wired alternatives be used whenever reasonably practicable, that wireless equipment not be placed unnecessarily close to children, and that the total electromagnetic environment be measured rather than relying solely on manufacturer specifications or SAR information.

I also recommend a clear warning or disclosure requirement for wireless products and installations when relevant testing has not been performed for the population or exposure scenario in question.

I also recommend that wireless devices intended for use by or in close proximity to children be subject to specific testing requirements. If a device has not been evaluated for use by or near children, including appropriate consideration of developing children and fetal exposure, its **labeling should clearly state that limitation** and its **use should be restricted** to adults unless and until appropriate child-specific evaluation has been completed.

This would establish a reasonable distinction between “**tested for this population and use scenario**” and “**not evaluated for this population and use scenario**.” Parents, schools, and childcare providers should not assume that testing conducted under adult, standardized

conditions necessarily establishes the appropriateness of a device for infants, children, or developing fetuses.

For products specifically marketed for infants or children, I believe this information should be particularly prominent and should be available before purchase. Where a wireless function is not essential to the product's primary purpose, a wired or non-transmitting alternative should also be clearly identified.

Q11(b). Pregnant women and fetuses

Pregnancy warrants separate consideration because the fetus is developing throughout pregnancy and may have different exposure characteristics from an adult. Research should evaluate exposure to the fetus from phones, wearables, Wi-Fi, Bluetooth devices, medical equipment, occupational sources, and environmental sources, including differences across stages of pregnancy.

The distinction between exposure to the pregnant person and estimated fetal exposure is also important. Research should not simply assume that adult exposure measurements fully characterize fetal exposure.

Additional targeted research and improved exposure characterization would be useful to evaluate typical environmental RF exposure and adverse pregnancy outcomes.

Q11(c). Older adults

Older adults may have different patterns of device use, longer occupational or environmental exposure histories, preexisting conditions, and greater use of implanted or external medical devices. Older adults may also have other health conditions that result in a compromised biological system, such as bone density, cardiovascular, respiratory and nervous systems. Research should consider these factors rather than assuming that exposure and susceptibility are identical across all age groups.

Q11(d). Individuals with implanted medical devices

This population requires particular attention to electromagnetic interference (EMI), which is distinct from the question of whether RF exposure causes biological effects. FDA recognizes electromagnetic compatibility and interference as important considerations for wireless and medical devices.

Assessment should therefore consider the frequencies, power levels, distances, operating conditions, and simultaneous use of wireless devices in realistic environments. Information provided to patients should make clear what electromagnetic compatibility testing has and has not been performed.

Q11(e). Workers with elevated occupational exposure

Workers in telecommunications, broadcasting, radar, industrial RF applications, and other settings may experience exposures that differ substantially from those of the general population. Personal dosimetry, environmental measurements, work practices, duration of exposure, distance from sources, and historical exposure records should be considered.

Q11(f). Individuals with preexisting medical conditions

Research should examine whether particular medical conditions, treatments, medications, or medical devices could alter exposure patterns or susceptibility. When individuals report symptoms that they associate with RF exposure, objective exposure measurements would provide a more useful basis for research than relying solely on subjective exposure estimates.

Q11(g). Other populations and exposure scenarios

Additional attention should be given to infants and neonates, children and adolescents with high device use, people who routinely wear wireless devices close to the body, individuals simultaneously exposed to multiple wireless sources, workers with high occupational exposure, and people who live, attend school, or work in close proximity to wireless infrastructure.

For children in particular, schools and childcare settings provide an opportunity to apply a precautionary exposure-minimization approach: use wired technology where practical, avoid unnecessary close-proximity wireless transmitters, measure the actual environment, and clearly disclose what testing has and has not been performed. This would provide parents and institutions with information needed to make informed decisions without assuming either that wireless exposure is harmful or that it is irrelevant.

Q12. What scientific evidence exists regarding potential adverse health effects associated with RF radiation exposure at levels below current federal exposure limits?

There are numerous experimental and observational studies in the submitted literature reporting biological effects at exposure levels below or near applicable regulatory limits. These studies include research involving oxidative stress, cellular signaling, DNA-related endpoints, reproductive function, development, neurological effects and other physiological measures.

Some studies are in-vitro experiments, some involve laboratory animals, and others are observational human studies. Accordingly, these findings should be regarded as evidence requiring further research and evaluation. Please see the list I submitted with Q18.

One reason below-limit research is important is that regulatory limits are not themselves biological experiments. A measured exposure below a regulatory threshold establishes that the exposure is below that threshold; it does not independently establish that every possible biological endpoint has been excluded.

The human sperm literature illustrates this distinction. Avendaño et al. reported decreased sperm motility and increased sperm DNA fragmentation following four hours of ex-vivo exposure to a Wi-Fi-connected laptop.

The study illustrates why exposure below an established limit should remain a subject of empirical investigation.

The appropriate federal research question is therefore not simply whether an exposure was below the existing limit. It is whether the existing limit has been adequately validated against the range of biological endpoints, exposure patterns, durations and susceptible populations encountered in the real world.

The existence of multiple studies reporting effects at levels below current exposure limits is important and, in my view, warrants continued evaluation of whether current exposure standards adequately represent **long-term, repeated, cumulative, and real-world exposure conditions**, particularly for children and other potentially sensitive populations.

Current RF exposure guidelines are primarily based on preventing established adverse effects associated with RF-induced heating. WHO describes heating as the principal established biological effect underlying current RF guidelines and states that possible effects from long-term, low-level exposure continue to be investigated. WHO is also undertaking a comprehensive health-risk assessment of RF fields.

The following studies illustrate the range of findings that have been reported at relatively low exposure levels.

Human studies and epidemiological observations

Children and cognitive/behavioral outcomes

- **Chiang et al. (1989)** reported effects involving children's memory, motor skills, and learning at reported RF exposure levels in the approximate range of **40,000–150,000 $\mu\text{W}/\text{m}^2$** . These findings are among the reasons that children's exposure warrants additional investigation.
- **Hocking et al. (1996)** reported an association between proximity to television transmitters and childhood leukemia. The exposure estimates reported in reviews of this work were approximately **2,000–80,000 $\mu\text{W}/\text{m}^2$** , with an elevated childhood leukemia incidence in the study area.
- **Durusoy et al. (2017)** studied 2,150 high-school students in Turkey, combining questionnaires concerning mobile-phone use and symptoms with measurements of electromagnetic fields in schools. The study investigated symptoms including headache, concentration difficulties, fatigue, sleep disturbances, and other complaints. The authors recommended further multidisciplinary research targeting children and dose-response relationships.

- **Cabré-Riera et al.** evaluated estimated whole-brain RF-EMF exposure in preadolescents and adolescents using several sources, including mobile phones, tablets, laptops, and far-field sources. This type of research is particularly relevant because it attempts to characterize exposure from multiple sources rather than treating exposure from a single device in isolation.

Cancer and leukemia

- **Dolk et al. (1997)** reported an increased incidence of adult leukemia within approximately 2 km of the Sutton Coldfield television/radio transmitter, with an observed-to-expected ratio of approximately 1.83. Exposure estimates in subsequent reviews have been reported in the approximate range of **13,000–57,000 $\mu\text{W}/\text{m}^2$** . These epidemiological findings are also relevant in the context of the International Agency for Research on Cancer (IARC) classification of RF-EMF as **Group 2B, “possibly carcinogenic to humans,”** in 2011. IARC described the human evidence at that time as limited and noted that bias and confounding could not be ruled out with reasonable confidence. This classification is a hazard classification and does not establish that a particular exposure level causes cancer.

Reproductive effects

A number of studies have reported effects involving male reproductive function, including sperm count, motility, testosterone, spermatogenesis, and testicular tissue. Examples in the literature include:

- **Kibona et al. (2013)** — reported associations involving male reproductive function at exposure levels reported in the approximate range of **1,700–10,000 $\mu\text{W}/\text{m}^2$** .
- **Sepehrimanesh et al. (2014)** — reported decreased testosterone and spermatogenesis following approximately four hours per day of RF exposure at a reported exposure level of approximately **1,000,000 $\mu\text{W}/\text{m}^2$** .
- **Adah et al. (2018)** and **Maluin et al. (2021)** — reported testicular tissue changes, including microscopic abnormalities and effects involving testosterone and sperm quality.
- **Karbalay-Doust et al. (2023)** and **De-Kun Li et al. (2010)** — reported findings involving sperm count, motility, or testicular tissue.

Animal and laboratory evidence

Additional research has reported biological effects at exposure levels below current public exposure limits, including:

- **Yurekli et al. (2006)**: increased free-radical production in rat cells at approximately **280,000 $\mu\text{W}/\text{m}^2$** .
- **Seyednour et al. (2011)**: changes in serum cortisol and other physiological measures in hamsters at approximately **200,000 $\mu\text{W}/\text{m}^2$** .
- **Dutta et al. (1989)**: altered calcium efflux at approximately **125,000 $\mu\text{W}/\text{m}^2$** .

- **Richter et al. (2000)**: reported a dose-response relationship involving cancer mortality among radar operators, with reported exposure estimates in the approximate range of **100,000–1,000,000 $\mu\text{W}/\text{m}^2$** . Occupational exposure reconstruction and other methodological limitations need to be considered.
- **Salford et al. (1994/1997)**: reported blood-brain barrier effects in experimental animals following RF exposure.
- **Sepehrimanesh et al. (2014)**: reported reproductive effects following repeated exposure.
- **Somosy et al. (1993)**: reported alterations in intracellular calcium in intestinal epithelial cells at approximately **5,000,000 $\mu\text{W}/\text{m}^2$** .
- **Walleczek (1991)**: reported effects involving immune-system function.
- **Persson et al.**: reported blood-brain barrier permeability changes following RF exposure.
- **Shuvy et al. (2014)**: reported effects involving calcium metabolism in cardiac cells at approximately **3,800 $\mu\text{W}/\text{m}^2$** .
- **Belyaev (2008)** and **Panagopoulos et al. (2019)**: reported cellular effects involving gene expression, chromatin, or DNA-related processes.

These laboratory findings are relevant to risk assessment because they can identify biological mechanisms or effects that can subsequently be investigated through animal and human studies.

Neurological, sleep, stress, and other reported effects

Other studies have investigated symptoms and physiological outcomes including headaches, fatigue, sleep disturbance, concentration difficulties, mood, and stress-related measures.

Examples include:

- **Keleş et al. (2021)** and **Pall (2015)**: reported neurological, sleep, headache, or concentration-related findings at relatively low exposure levels.
- **Navarro et al.**: reported fatigue, headaches, and sleep-related complaints in populations living near base stations.
- **Durusoy et al. (2017)**: investigated headaches, irritation, behavioral and concentration difficulties, and other symptoms among schoolchildren while also measuring school electromagnetic-field levels.
- **Belyaev et al. (2016)**: reviewed evidence concerning possible effects on sleep, mood, and neurological function.
- **Halgamuge (2013)**: examined possible relationships between prolonged EMF exposure, stress hormones, and circadian rhythms.

Electromagnetic hypersensitivity and reported symptoms

Research has also examined people who report symptoms that they attribute to electromagnetic-field exposure, sometimes referred to as electromagnetic hypersensitivity (EHS) or idiopathic environmental intolerance attributed to EMF.

Studies such as **Belpomme et al. (2018)** have reported physiological or clinical differences in individuals reporting EHS. However, the relationship between these findings and RF exposure remains scientifically disputed.

I believe these findings support continued examination of several questions:

1. **Are current limits adequately protective against long-term and repeated exposure, rather than primarily established acute effects?**
2. **Do current compliance methods adequately represent actual exposure from multiple simultaneous RF sources?**
3. **Are children and developing fetuses adequately represented in exposure assessment and dosimetry?**
4. **Does proximity to transmitting devices require greater consideration than generalized environmental averages?**
5. **Should frequency, modulation, pulsing, duty cycle, duration, and cumulative exposure be incorporated more explicitly into exposure assessment?**
6. **Should RF exposure research be integrated with measurements of the broader electromagnetic environment, including electric and magnetic fields from electrical systems and equipment?**
7. **Can longitudinal studies using objective personal and environmental exposure measurements better determine whether reported associations persist over time?**

I would also encourage federal agencies to distinguish between “**below the current limit**” and “**demonstrated to be without biological effect.**” A regulatory limit represents the boundary established under a particular scientific and regulatory framework; it does not mean that every biological response reported below that value has been disproven.

WHO itself distinguishes between a biological effect and an adverse health effect and notes that possible effects of long-term, low-level RF exposure remain an area of research. WHO is currently undertaking a comprehensive RF health-risk assessment, which further indicates that the scientific evaluation of these questions remains active.

For that reason, I believe the evidence below current limits should be treated as a reason for **continued investigation, improved exposure measurement, applying strategies to mitigate exposure with particular attention to children and other potentially sensitive populations.**

Q13. According to scientific evidence, how do the technologies below affect cumulative exposure patterns?

The assessment of RF exposure should reflect the fact that people are no longer exposed primarily to a single wireless device. A typical modern environment may contain simultaneous or sequential exposure from cellular networks, Wi-Fi access points, Bluetooth devices, wearable technologies, smart meters, wireless security systems, IoT devices, smart appliances, wireless medical devices and other transmitters.

The scientific and regulatory challenge is therefore to characterize exposure as a changing environmental condition rather than as a single device-specific measurement.

This should include:

- the number of transmitting sources;
- frequency and bandwidth;
- power density;
- modulation and pulsing;
- duty cycle;
- distance from each source;
- proximity to the body;
- duration of exposure;
- simultaneous transmission;
- intermittent versus continuous transmission;
- indoor versus outdoor exposure;
- shielding and building characteristics; and
- cumulative exposure over days, months and years.

Research should also determine whether exposures from multiple sources can be meaningfully combined for risk assessment or whether certain characteristics of the signals require separate evaluation.

For example, human experimental research has demonstrated that a cell phone placed next to the head can produce measurable regional changes in brain glucose metabolism during a relatively short exposure.

Research on children's RF absorption further indicates that exposure cannot necessarily be represented by assuming a uniform adult body.

The increasing number and proximity of wireless transmitters therefore make cumulative exposure assessment an important federal research priority.

Federal agencies should develop standardized methods for measuring real-world exposure over time rather than relying exclusively on laboratory measurements of individual products.

Several studies report data as it relates to combined exposure patterns.

Boussad et al. (2022), in *Longitudinal Study of Exposure to Radio Frequencies at Population Scale*, analyzed crowd-sourced RF measurements from 254,410 unique users in 13 countries between 2017 and 2020. The study examined exposure from cellular antennas, Wi-Fi access points, and Bluetooth devices. It reported changes in overall exposure over the study period and identified Wi-Fi as a major contributor. For approximately half of the participants, personal Wi-Fi routers and Bluetooth devices contributed more than 50% of their estimated total exposure. This research demonstrates the value of examining multiple sources together and over time rather than relying exclusively on measurements of cellular infrastructure.

Research involving Swiss adolescents has also examined personal exposure from multiple sources. A study published in 2017 measured personal RF exposure in 90 adolescents over three consecutive days and combined those measurements with dose calculations for wireless-device use. Mobile phones and cellular base stations were the largest contributors to measured personal exposure, while Wi-Fi at home and school contributed a smaller proportion in that particular study. The research is important because it illustrates that the relative contribution of different sources depends on actual device use and the individual's environment.

A more recent 2026 study, *Personal Radio Frequency Electromagnetic Field Exposure Among Swiss Adolescents in the 5G Era*, examined personal exposure patterns among adolescents after the introduction of 5G. The study reported Wi-Fi and Bluetooth as the largest combined contributor to total exposure, while 5G TDD bands contributed a relatively small proportion. It also compared exposure across different environments, including homes and transportation systems. This is particularly relevant to evaluating exposure because it considers multiple technologies and real-world activities rather than treating 5G as an isolated source.

These studies support the need for cumulative exposure assessment that considers multiple technologies, simultaneous operation, proximity, duration, and the actual environments in which people live, work, learn, travel, and receive medical care.

Q13(a). 5G

Expósito et al. (2024), in *Human Exposure to EMF from 5G Base Stations: Analysis, Evaluation and Comparison of Different Assessment Methods*, compared broadband field probes, spectrum analyzers, and drive-test scanners for evaluating exposure from 5G base stations. The research demonstrates that measurement methodology and variations in signal levels are important considerations when characterizing exposure.

A 2025 UK study, *In-Situ Measurements of Radiofrequency Electromagnetic Fields Around 5G Macro Base Stations in the UK*, measured RF fields at 56 active 5G macro base stations across 30 publicly accessible locations. It assessed background conditions and different network-activity scenarios and measured total RF exposure across multiple frequency bands. The researchers reported that 4G downlink was the dominant contributor to total RF exposure at the measured locations, while 5G contributed less than 10% on average.

Piro et al. / wearable 5G antenna exposure study (2023). *Assessment of EMF Human Exposure Levels Due to Wearable Antennas at 5G Frequency Band*. This study modeled wearable antennas at approximately **3.5 GHz and 26.5 GHz** positioned on the trunk. Exposure was concentrated primarily in superficial tissue immediately below the antenna, with exposure distributions changing with distance from the antenna.

An important consideration is that 5G does not replace all previous wireless technologies. A person may simultaneously be exposed to 5G cellular signals, 4G/LTE, Wi-Fi, Bluetooth, and other RF sources. Assessing 5G in isolation may therefore fail to characterize a person's cumulative exposure.

An additional consideration with 5G is the relationship between signal penetration, transmitter density, and actual exposure. Higher-frequency 5G signals, particularly millimeter-wave frequencies, generally have shorter propagation distances and greater attenuation from walls and other materials. This is one reason 5G network architectures can require greater densification, including additional small cells and antennas located on buildings, utility poles, streets, and potentially inside buildings.

It would therefore be incomplete to characterize the public-health implications of 5G solely by stating that higher-frequency signals penetrate the body or buildings less effectively. Reduced penetration can decrease exposure to deeper tissues, but a network that relies on more closely spaced transmitters changes the spatial and temporal pattern of exposure. A person may be farther from a conventional macrocell but much closer to a small-cell antenna or other local or non 5G transmitter.

There is also a legitimate engineering argument that increased network density can reduce exposure because shorter transmission distances allow both infrastructure and mobile devices to operate at lower power. Some measurements have reported lower 5G uplink transmit power than 4G under the conditions studied, and studies of 5G small cells have found that exposure to non-users can be substantially reduced by beamforming. These findings are important and should be considered alongside concerns about network densification rather than assuming that either greater density or higher frequency automatically produces greater or lesser exposure. This, however, must include the additional Wi-Fi and other transmitters still required to support 5G network configurations.

For this reason, I believe 5G exposure should be evaluated through actual measurements in representative real-world environments rather than inferred primarily from frequency or the number of transmitters. Measurements should account for the number and location of transmitters, frequency bands, antenna characteristics, beamforming, network utilization, distance from people, indoor and outdoor conditions, simultaneous sources, and exposure over realistic periods. The relevant question is not simply whether an individual 5G signal penetrates a wall less effectively, but what cumulative RF environment people experience as the network architecture changes.

Q13(b). 6G

6G is still under development, so there is not yet a comparable body of long-term population exposure data from deployed 6G networks.

Nevertheless, 6G should be incorporated into exposure research before widespread deployment rather than waiting until the technology is ubiquitous. Exposure assessment should consider anticipated frequencies, antenna architectures, beamforming, distributed networks, device density, and potential proximity to users.

Baseline measurements and exposure modeling before widespread deployment could provide valuable information for later population-health studies. Research should also examine how 6G may operate alongside existing cellular networks, Wi-Fi, Bluetooth, and other wireless systems.

Q13(c). Wi-Fi

Foster (2007), in *Radiofrequency Exposure from Wireless LANs Utilizing Wi-Fi Technology*, reported measurements from 356 locations at 55 sites across the United States and several European countries. The sites included residences, commercial spaces, healthcare facilities, educational institutions, and public spaces. The study measured Wi-Fi fields in relation to background RF fields and examined exposure near access points and operating laptops.

A 2017 study, *Exposure to Radiofrequency Electromagnetic Fields from Wi-Fi in Australian Schools*, measured typical and peak RF levels in 23 schools. The researchers assessed Wi-Fi alongside other RF sources in classrooms and schoolyards. This is particularly relevant because it provides actual measurements in environments where children spend many hours each day.

Jalilian et al. (2019), in a systematic review of public exposure in everyday microenvironments, evaluated measurements from homes, schools, offices, outdoor environments, and transportation systems. The review found that exposure patterns differed by environment and that cellular base-station downlink signals were important contributors in many outdoor settings.

For cumulative exposure assessment, it is important to consider both access points and the numerous connected devices using the network. Schools and daycares deserve particular attention because the location of access points relative to children's seating, sleeping, or activity areas may influence individual exposure.

Q13(d). Satellite communications

Published research specifically characterizing cumulative personal exposure from satellite communications in everyday residential and community environments remains limited. This is an area where additional research would be valuable, particularly as satellite connectivity becomes more widely integrated into consumer devices, vehicles, emergency communications, and other systems.

Q13(e). Internet of Things (IoT)

Joyner et al. (2024), in *Estimates and Measurements of Radiofrequency Exposures in Smart-Connected Homes*, investigated 55 individual devices across 23 device categories, including measurements in two smart apartments containing more than 50 and more than 100 IoT devices. The study examined how multiple devices operating together contributed to overall exposure and developed a method for estimating exposure from combinations of devices.

McKenzie et al. (2024), in *Assessment of Radio Frequency Fields in the 2.45 GHz Band Produced by Smart Home Devices*, measured RF fields from Wi-Fi- and Bluetooth-connected smart-home devices under simulated high-activity conditions. The researchers examined field levels and duty cycles, demonstrating the importance of measuring actual transmission patterns rather than assuming that all connected devices transmit continuously.

Q13(f) Wearables

Wearables deserve particular attention because they can operate directly on or immediately adjacent to the body for prolonged periods.

Examples include smart watches, fitness trackers, wireless medical monitors, hearing-related devices, connected clothing, location devices, and other body-worn technologies.

Personal exposure research involving adolescents and other populations has examined contributions from mobile phones, Wi-Fi, Bluetooth, and environmental sources. However, more research specifically assessing the cumulative contribution of multiple simultaneously worn wireless devices would be valuable.

Karthik V, Rao TR. (2018). *SAR investigations on the exposure compliance of wearable wireless devices using infrared thermography.* This is directly relevant because it concerns **wearable wireless devices operating in close proximity to the body** and specifically discusses the exposure implications of wearable technology.

Lemaire et al. / wearable antenna dosimetry study (2022). *Human Exposure Assessment to Wearable Antennas: Effect of Position and Interindividual Anatomical Variability.* The researchers modeled a 2.45-GHz wearable antenna in six realistic configurations on male and female anatomical models. The highest exposure varied with the antenna's position, and the calculated exposure was concentrated in tissue immediately beneath the antenna.

Piro et al. / wearable 5G antenna exposure study (2023). *Assessment of EMF Human Exposure Levels Due to Wearable Antennas at 5G Frequency Band.* This study modeled wearable antennas at approximately **3.5 GHz and 26.5 GHz** positioned on the trunk. Exposure was concentrated primarily in superficial tissue immediately below the antenna, with exposure distributions changing with distance from the antenna.

Roser K, Schoeni A, Struchen B, et al. (2017). *Personal radiofrequency electromagnetic field exposure measurements in Swiss adolescents.* The study measured 90 adolescents aged

13–17 for three days across 13 frequency bands and combined personal measurements with dosimetric calculations. Mobile phones were the largest contributor to measured exposure, with environmental sources including base stations, WLAN access points and other phones also contributing.

Calvente et al. / SCAMP cohort (2022). *Personal radiofrequency electromagnetic field exposure of adolescents in the Greater London area in the SCAMP cohort and the association with restrictions on permitted use of mobile communication technologies at school and at home*. This measured 148 adolescents for a median of 47 hours across 16 frequency bands, including mobile-phone uplink/downlink, Wi-Fi, DECT and broadcast sources. It provides another real-world demonstration that adolescent exposure is a combination of personal device use and environmental RF sources.

Birks et al. / European child-parent study (2018). *Personal exposure to radio-frequency electromagnetic fields in Europe: Is there a generation gap?* This study used simultaneous 24–72-hour personal measurements in **294 parent-child pairs** in five European countries. Measurements distinguished environmental downlink, mobile-phone uplink, broadcast, DECT and Wi-Fi sources and examined differences associated with activities and behavior.

Swiss adolescent 5G-era study (2026). *Personal radio frequency electromagnetic field exposure among Swiss adolescents in the 5G era*. It measured 143 adolescents for approximately 72 hours using an exposimeter covering 35 frequency bands. Wi-Fi/Bluetooth accounted for the largest categorized contribution (35%), followed by broadcast (31%), uplink (19%), downlink (10%), and 5G TDD (4%). Importantly, the authors specifically state that personal measurements can underestimate contributions from sources emitting close to the body.

ITU-T K.91 (2024). *Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields*. The ITU guidance explicitly addresses simultaneous exposure and describes cumulative exposure calculations in which contributions from different frequencies are considered together.

ITU-T K.160 (2025). *Assessment of human exposure to radiofrequency electromagnetic fields from wireless communication devices operating close to the human body*. This identifies device category, usage position, frequency, power, operating mode and measurement distance as relevant factors. It also addresses simultaneous transmission and total exposure ratio.

Q13(g) Smart homes and appliances

Smart homes can create a connected RF environment through smart televisions, appliances, thermostats, lighting systems, security cameras, doorbells, voice assistants, sensors, hubs, and other connected devices.

The Joyner et al. (2024) and McKenzie et al. (2024) studies provide published measurements of RF emissions from multiple smart-home devices and connected equipment. They are useful

because they examine actual devices and the combined environment rather than relying solely on manufacturer specifications.

The cumulative exposure pattern will depend on how many devices transmit, where they are located, how frequently they communicate, and whether they operate continuously or intermittently.

An additional consideration is that some devices may remain capable of wireless transmission even when the primary consumer-facing function appears to be turned off or when the device is in standby. This makes transparent disclosure of actual transmitting states important for meaningful exposure assessment.

Where a wired alternative is practical, it should be available and clearly identified.

Q13(h) Smart cities

Smart-city infrastructure can increase the number of wireless systems operating in public spaces. These may include connected traffic systems, environmental sensors, public Wi-Fi, transportation systems, utility infrastructure, communications equipment, and other networked devices.

Published research on everyday RF exposure provides useful information about the combined RF environment in urban and public spaces. Jalilian et al. (2019) reviewed measured exposures across different microenvironments, including outdoor locations and transportation systems. Boussad et al. (2022) also demonstrated the feasibility of assessing population exposure to multiple wireless sources over several years and across numerous countries.

Kim BC, Kim WK, Lee GT, et al. (2014). *Evaluation of radiofrequency exposure levels from multiple wireless installations in population dense areas in Korea*. For these devices, distance becomes especially important. A transmitter several feet away from a person represents a different exposure scenario from a transmitter worn continuously against the body. Exposure assessment should therefore consider actual wearing position, duration, transmission frequency, power control, and simultaneous operation with the person's phone, Wi-Fi, Bluetooth accessories, and other devices.

However, additional research is needed to characterize the combined exposure from the full range of smart-city infrastructure, particularly as more systems are deployed in the same locations.

The exposure pattern is likely to vary considerably by location and time. Population studies should therefore consider measurements across residential areas, schools, workplaces, transportation corridors, public spaces, and other locations where people spend significant amounts of time.

Q13(i) Autonomous and connected vehicles

Autonomous and connected vehicles may incorporate multiple wireless technologies simultaneously, including cellular communications, Wi-Fi, Bluetooth, vehicle-to-vehicle and vehicle-to-infrastructure communications, radar, sensors, and other communication systems. Passengers may therefore experience several RF sources within the vehicle while also being exposed to external cellular and other wireless infrastructure.

Published research on RF exposure in transportation environments, including the systematic review by Jalilian et al. (2019), provides a foundation for understanding exposure in vehicles and public transportation. However, the combined exposure from the multiple communication and sensing systems used in increasingly connected and autonomous vehicles warrants more specific investigation.

Exposure assessment should consider the combined environment inside the passenger compartment, including the location of antennas and transmitters, rather than evaluating each wireless system independently.

Q13(j) Wireless medical devices

Wireless medical devices present a somewhat different issue because wireless communication can provide important medical benefits. Examples include wireless patient monitoring, telemetry, remote monitoring, and devices that communicate with phones, tablets, or other medical systems.

FDA recognizes that wireless medical devices operate in increasingly crowded RF environments and addresses wireless coexistence, electromagnetic compatibility, and the interaction of wireless medical devices with other RF systems.

For cumulative exposure research, wireless medical devices should be considered both as potential sources of RF exposure and as devices operating within an increasingly dense RF environment. Research should examine actual operating conditions in healthcare facilities, including multiple devices operating simultaneously and devices used close to or on patients for extended periods.

Q13(k) Communication-enabled smart meters

Communication-enabled smart meters can add another RF source to residential and commercial environments. Their exposure pattern is different from that of a continuously transmitting device because communications may occur intermittently, depending on the meter design and communications network.

Tell, Kavet, and Mezei (2013), in *Characterization of Radiofrequency Field Emissions from Smart Meters*, measured emissions from smart meters operating in northern California and examined their transmission patterns and duty cycles. The researchers used measurements and utility transmission data to characterize how frequently the meters transmitted.

A 2020 study, *Spatial and Temporal Assessment of Radiofrequency Electromagnetic Fields Emitted by Smart Meters and Smart Meter Banks in Urban Environments*, measured emissions around individual meters and groups of meters at multiple urban locations. It examined both spatial field levels and transmission duty cycles, demonstrating that a bank of meters can produce a different exposure pattern from an individual meter.

These studies show why assessment should measure actual transmission patterns rather than assume either continuous transmission or no meaningful exposure. Where smart meters communicate through wireless mesh networks, the assessment should also consider nearby meters and other network infrastructure rather than evaluating one meter in isolation.

This is another area that federal regulations should require the option for a wired solution. Typical residences have a wired network connection that should be mandated to permit required usage data to transmit without participation in the neighborhood Utility wireless network.

Q14 What scientific evidence exists regarding potential adverse environmental effects associated with RF radiation?

The scientific literature identified in the materials submitted with this response includes research involving birds, trees, insects and other biological systems. Please see Q18 for the list of studies.

RF radiation is an environmental exposure that does not affect humans alone. Radiofrequency electromagnetic fields interact physically with biological organisms, including plants, insects, birds, mammals, and other wildlife. As wireless communications infrastructure has expanded, RF exposure has become an increasingly widespread environmental influence.

A large systematic evidence map of anthropogenic RF-EMF exposure and animals and plants identified **334 relevant studies, including 237 studies involving fauna and 97 involving flora**. The studies covered frequencies from 100 kHz to 300 GHz, with the majority examining frequencies between 300 and 3000 MHz. Importantly, the exposure levels in most of the studies were below applicable ICNIRP limits. The evidence was concentrated in studies of insects and birds, particularly reproduction, development, and behavior, and in studies of plants involving germination and growth.

A more recent systematic review specifically examining insects also identified research investigating potential biological effects of electromagnetic fields, including exposures associated with cellular networks and other technological infrastructure. The authors noted the need to understand RF-EMF as one of multiple anthropogenic environmental factors affecting insects.

Insects:

Insects are particularly important because they are fundamental to pollination, food webs, decomposition, and ecosystem function. Research has examined potential effects of RF-EMF on insect behavior, development, reproduction, and other biological processes. Given the

widespread deployment of wireless infrastructure and the ecological importance of insects, this area warrants substantially more field-based research.

Birds:

Birds have been one of the more frequently studied groups in the environmental RF literature. Research has investigated development, behavior, reproduction, orientation, and other biological outcomes. However, much of the available evidence comes from laboratory or controlled studies rather than long-term observations of wild populations. The potential implications for migration, reproduction, nesting, and population-level effects therefore remain important research questions.

Plants:

Research has examined effects on seed germination, growth, development, and other physiological processes. The systematic evidence map identified grains and legumes as particularly well represented in the existing literature.

Plants also warrant attention because they cannot move away from an environmental exposure. A plant growing adjacent to a wireless installation may experience exposure continuously or for substantial portions of its life cycle, depending on the source and environment.

Other animals and wildlife:

Research has also included mammals and other vertebrates, although the evidence base is less extensive than for insects and birds. Additional research should examine a broader range of species and should consider reproductive, developmental, behavioral, neurological, immune, and other biological outcomes.

The 2019 international workshop review concluded that the effects of RF-EMF on flora, fauna, and ecosystems are not well studied and recommended additional research, particularly because appropriate environmental field studies are scarce.

One particularly important issue is that human RF exposure guidelines are not necessarily environmental protection standards.

The systematic evidence map specifically notes that current ICNIRP guidelines are based on knowledge of effects on the human body and that there are no recognized international guidelines specifically intended to protect animals and plants from RF-EMF exposure. Whether human exposure guidelines adequately protect the environment remains an active subject of debate.

This is an important distinction. A level determined to be acceptable for a human exposure scenario does not automatically establish that the same exposure level is appropriate for every species or ecosystem.

Q15: What types of scientific evidence should be considered when evaluating RF exposure associated with wireless infrastructure?

Scientific evaluation of RF exposure associated with wireless infrastructure should consider measured environmental and personal exposure, source-specific technical information, population-based studies, and research examining potential biological and ecological effects. Environmental RF research should include:

- **Long-term field measurements** around cellular infrastructure, broadcast facilities, Wi-Fi-dense environments, and other significant RF sources, with measurements repeated over time to characterize spatial and temporal variation.
- **Longer-duration and, where scientifically justified, multi-generation studies**, particularly for reproductive and developmental endpoints that may not be adequately characterized by short-term experiments.
- **Studies using realistic environmental exposure patterns**, including multiple frequencies, time-varying exposure, and simultaneous sources where those conditions reflect actual environments.
- **Standardized environmental measurement protocols**, including standardized reporting of frequency, power density or field strength, exposure duration, modulation or signal characteristics, measurement location, instrumentation, calibration, and other relevant exposure parameters. Lack of standardization has been identified as a limitation in the existing environmental literature.
- **Research at exposure levels below existing human RF limits**. The systematic evidence map found that much of the existing environmental literature has already examined relatively low exposures, generally below ICNIRP limits. This literature should be strengthened with higher-quality, standardized studies conducted under realistic environmental conditions.

15(a) Proximity to homes, schools, childcare facilities, healthcare facilities, and/or workplaces

Schools and childcare facilities deserve particular consideration because children may spend a substantial portion of their developmental years in these environments and have relatively little control over the wireless infrastructure around them.

Healthcare facilities also deserve specific consideration because patients may be particularly dependent on electronic and wireless medical equipment, and because RF exposure and electromagnetic interference are separate but potentially relevant issues. FDA recognizes the importance of electromagnetic compatibility and assessment of the RF environment in healthcare settings.

I would recommend **mandatory baseline and periodic RF measurements at schools, childcare facilities, healthcare facilities, and other designated sensitive locations when significant wireless infrastructure is present nearby**. Measurements should be publicly accessible in a standardized format and should identify, to the extent technically feasible:

- measured RF levels;
- frequencies detected;
- measurement location and height;
- date and time;
- measurement duration;
- relevant transmitting sources;
- whether measurements represent average, maximum, or other statistical conditions;
- significant changes in infrastructure or operating conditions; and
- the measurement methodology and equipment used.

Relevant evidence to consider for this category includes:

- **Environmental RF measurements** at and around these locations, including measurements at representative occupied areas and, where appropriate, different heights and distances.
- **Personal-exposure studies** that compare measured exposure with estimates based on distance, antenna location, or modeled exposure.
- **Repeated measurements under different operating conditions** to characterize variation by time, transmitting activity, frequency, and environmental conditions.
- **Studies of sensitive populations and settings**, including children in schools and childcare facilities and patients in healthcare settings.
- **Electromagnetic compatibility research** in healthcare facilities, because RF exposure and potential interference with medical equipment are separate but relevant issues.

15(b) Cumulative neighborhood exposure

Relevant evidence includes:

- **Personal and environmental exposure studies** measuring the combined contribution of multiple sources, rather than attributing exposure to the nearest antenna alone.
- **Longitudinal and repeated-measurement studies** examining how exposure varies across locations, times, and operating conditions.
- **Frequency-specific measurements** that distinguish cellular uplink and downlink, 5G, Wi-Fi, Bluetooth, broadcast, and other relevant sources where technically feasible.
- **Exposure assessments that account for simultaneous sources and multiple frequencies**, using appropriate measurement and assessment methods.
- **Population-based exposure studies** examining differences among individuals and environments and identifying the principal contributors to measured exposure.

These studies can help establish how much different sources contribute to the RF environment and how exposure varies over time. They should also report their limitations, including whether measurements capture intermittent transmissions, represent typical or maximum conditions, and adequately characterize longer-term exposure.

15(c) Antenna density

Relevant evidence includes:

- **Field measurements in areas with different antenna densities**, using comparable methods and documenting the locations and characteristics of relevant installations.
- **Studies of combined exposure from co-located or nearby transmitters**, including the contributions of multiple operators and technologies.
- **Spatial mapping and measurement campaigns** examining how exposure varies within neighborhoods, including at occupied buildings and other locations where people spend time.
- **Repeated measurements** to determine whether observed differences persist under varying traffic and transmitting conditions.
- **Studies comparing modeled exposure with measured RF levels**, to assess how reliably infrastructure information predicts exposure in the surrounding environment.

The number of antennas or installations in an area should not, by itself, be treated as a measure of exposure. Antenna density is an infrastructure characteristic; actual exposure depends on the configuration and operation of the installations and on the surrounding environment. Studies should therefore examine antenna density alongside measured RF levels and other relevant variables.

15(d) Small-cell deployment

Relevant evidence includes:

- **In-situ measurements around active small cells** at multiple distances and locations accessible to the public.
- **Measurements under different operating conditions**, including background conditions, typical traffic, and appropriately characterized higher-traffic or worst-case conditions.
- **Frequency-specific and total RF measurements** that account for small cells alongside other sources in the surrounding environment.
- **Studies examining the effects of installation height, antenna orientation, line of sight, nearby structures, and distance** on measured exposure.
- **Comparisons between predicted and measured exposure**, including assessments of whether assumptions used in deployment models accurately characterize real-world conditions.
- **Repeated measurements following deployment or material changes in configuration or operation**, where needed to characterize changes in the RF environment.

Recent in-situ research around active 5G macro base stations and studies of 5G small cells demonstrate the value of measuring actual RF levels across locations and operating conditions. Similar standardized measurement approaches should be used to evaluate small-cell deployments, particularly where installations are close to homes, workplaces, schools, childcare facilities, or other occupied areas.

15(e) Livestock

Relevant evidence should include both direct measurements of RF exposure in livestock environments and research examining potential biological and animal-health outcomes.

Relevant study types include:

- **Environmental field measurements** on farms and near livestock housing, documenting frequencies, measured levels, exposure duration, and relevant transmitting sources.
- **Animal studies under characterized exposure conditions**, with appropriate comparison groups and sufficient exposure information to allow replication.
- **Reproductive and developmental studies**, including fertility, pregnancy, fetal development, birth outcomes, and effects on offspring.
- **Studies of growth, behavior, physiology, health, and survival**, using scientifically justified and clearly defined endpoints.
- **Longer-duration and, where justified, multigenerational studies**, particularly when investigating outcomes that may not be adequately assessed in short-term experiments.
- **Population and farm-level studies** that examine whether observed outcomes are associated with measured exposure while accounting for relevant confounding factors.
- **Ecological field studies** examining potential effects on insects, birds, plants, and other organisms relevant to agricultural environments and ecosystem function.

Systematic reviews of experimental studies in non-human mammals have identified research on reproductive and developmental outcomes. Environmental reviews have similarly identified a need for more standardized field research and better evidence on population- and ecosystem-level outcomes. These gaps support further investigation of:

- **Wildlife monitoring** in areas with different measured RF exposure levels, including appropriate control or comparison environments.
- **Insect studies**, including pollinators and other ecologically important species, with attention to behavior, reproduction, development, survival, and population-level outcomes.
- **Bird studies** involving reproduction, development, behavior, migration, and orientation, particularly under realistic environmental exposure conditions.
- **Plant studies** involving germination, growth, reproduction, development, and other biologically relevant endpoints.
- **Ecosystem-level research** examining whether effects observed in individual organisms are associated with changes in populations, species interactions, or ecological relationships. Existing reviews have specifically identified the lack of such field and ecosystem-level evidence as an important limitation.

Q16. What are the highest priority research gaps regarding EMF and RF radiation and public health that the federal health agencies should address?

I believe that federal research priorities should include **long-term, independent investigation of cumulative and chronic exposure**, children and pregnancy, reproductive and developmental outcomes, neurological and sleep-related effects, cardiovascular and other biological effects, environmental and ecological effects, and exposure associated with evolving technologies such as 5G, future wireless systems, IoT devices, wearables, smart homes, wireless medical devices, and increasingly dense wireless infrastructure. Research should be sufficiently broad to investigate questions that may have important public-health or regulatory implications, including questions that could ultimately lead to changes in technology standards or industry practices.

The federal government should therefore prioritize research that answers four fundamental questions:

1. **What are people, children, pregnant women, workers, and the environment actually exposed to?**
2. **How do those exposures change over time and when multiple sources operate simultaneously?**
3. **What biological, health, developmental, reproductive, and ecological effects are associated with those exposure patterns?**
4. **Are existing exposure assessment methods and protective standards adequately addressing the exposure conditions created by modern wireless technology?**

A coordinated federal research program addressing these questions would provide a much stronger scientific foundation for future public-health guidance, exposure standards, infrastructure decisions, consumer information, and research priorities as wireless technologies continue to expand.

1. Real-world, cumulative exposure assessment

One of the most important gaps is the lack of standardized, large-scale measurement of the RF/EMF exposures people actually experience throughout their daily lives.

Research should develop and validate methods for measuring exposure over hours, days, weeks, and longer periods, including:

- cellular networks and cellular devices;
- Wi-Fi and Bluetooth;
- wireless IoT devices;
- wearables;
- smart-home devices and appliances;
- wireless medical devices;

- smart meters;
- wireless infrastructure and small cells;
- satellite communication systems; and
- other RF-emitting technologies.

Exposure characterization should account for frequency, power density, field strength, modulation, pulsing, duty cycle, bandwidth, duration, distance, proximity to the body, and simultaneous exposure from multiple sources.

This is particularly important because standardized device testing and SAR measurements do not provide a complete picture of cumulative environmental exposure. A major research priority should therefore be the development of standardized personal and environmental RF exposure monitoring methods that can be used consistently across epidemiological studies.

A 2025 ICNIRP statement itself identifies gaps involving dosimetry and exposure assessment, including exposure to multiple EMF sources and how body temperature changes during multiple-source exposure.

2. Long-term health effects of chronic, low-level exposure

Longitudinal research is needed to evaluate the potential health effects of prolonged exposure at levels commonly encountered in homes, schools, workplaces, public spaces, and near wireless infrastructure.

Priority outcomes should include:

- cancer;
- neurological and cognitive outcomes;
- sleep and circadian function;
- cardiovascular and autonomic effects;
- reproductive and fertility outcomes;
- pregnancy and birth outcomes;
- endocrine effects;
- immune and inflammatory effects;
- oxidative stress and cellular effects; and
- developmental outcomes.

Studies should evaluate cumulative exposure rather than relying primarily on whether an individual exposure event exceeds an acute limit.

WHO continues to identify RF health-risk assessment as an area requiring systematic review, including cancer, reproductive outcomes, cognitive effects, symptoms, heating, and oxidative stress.

3. Children, infants, pregnancy, and fetal exposure

This should be a particularly high-priority research area.

Federal research should specifically characterize RF/EMF exposure and potential health effects in:

- fetuses;
- pregnant women;
- infants;
- children;
- adolescents; and
- developing organs and tissues.

Research should address age-specific anatomy and physiology, differences in device use, proximity to transmitting devices, exposure duration, and developmental windows.

This is not a new research question. A National Academies workshop commissioned by FDA identified characterization of exposure in juveniles, children, fetuses, and pregnant women, as well as prospective epidemiological studies of children and pregnant women, as research needs. FDA continues to identify these areas among the research gaps associated with wireless devices.

The fact that these questions were identified many years ago makes it especially important that they now be addressed using modern exposure measurement methods and current omnipresent wireless technologies.

4. Multiple simultaneous RF sources and cumulative exposure

Most real-world exposure does not come from one isolated transmitter.

Research should examine realistic combinations of simultaneous exposures, such as:

- a cellular phone operating near the body while Wi-Fi is active;
- Bluetooth devices operating simultaneously with cellular and Wi-Fi;
- multiple wireless devices in a classroom;
- several wireless devices operating in a home;
- wearables combined with nearby phones and wireless infrastructure;
- multiple cellular bands and nearby small cells; and
- environmental background exposure combined with personal-device exposure.

Studies should determine whether frequency, modulation, pulsing, duty cycle, duration, proximity, and simultaneous operation alter biological responses compared with isolated exposures.

This is an important gap because a person can be exposed to numerous RF sources even though each individual device is operating within its applicable limit.

5. Better research on non-thermal and biological mechanisms

A major research priority should be understanding biological effects that may occur at exposure levels below those associated with measurable tissue heating.

Research should investigate potential mechanisms involving:

- oxidative stress;
- cellular signaling;
- calcium signaling;
- gene expression and DNA-related effects;
- membrane and ion-channel activity;
- blood-brain barrier function;
- mitochondrial function;
- endocrine signaling;
- reproductive biology;
- neurological processes; and
- other cellular or molecular pathways identified by reproducible research.

This should include well-controlled laboratory studies, animal studies, human studies, and mechanistic research designed to determine whether reported biological findings are reproducible and biologically meaningful.

ICNIRP's 2025 knowledge-gap statement specifically identifies additional research needs concerning mechanisms, thresholds, and dosimetry relevant to RF exposure guidelines.

6. Improved epidemiological studies using objective exposure measurements

Many epidemiological studies have necessarily relied on estimates of exposure based on factors such as phone use, distance from infrastructure, job category, or residential location. Future studies should incorporate objective exposure measurements whenever possible.

Large prospective cohorts should collect standardized information about:

- residential exposure;
- workplace exposure;
- school and childcare exposure;
- personal device use;
- wearable-device exposure;
- proximity to wireless infrastructure;
- frequency and duration of exposure;
- cumulative exposure over time; and
- simultaneous exposure from multiple sources.

This would substantially improve exposure classification and reduce uncertainty in epidemiological research.

The federal government should consider integrating RF exposure assessment into existing longitudinal environmental-health cohorts where practical rather than creating entirely separate research populations.

7. Research specifically in schools, childcare, healthcare, and other high-occupancy environments

Federal research should characterize exposure in locations where people spend substantial amounts of time, particularly children.

This should include:

- schools;
- childcare and daycare facilities;
- hospitals and clinics;
- nursing and assisted-living facilities;
- workplaces;
- public transportation;
- residential buildings; and
- other environments with substantial wireless-device density.

Research should measure actual exposure rather than estimating it solely from the number of wireless devices or access points present.

For schools and childcare facilities in particular, studies should examine the effect of distance between children and wireless transmitters, the number of simultaneous transmitters, duration of exposure, and the availability of wired alternatives.

8. Research on wireless infrastructure and neighborhood exposure

More research is needed on exposure from the built wireless environment itself.

Studies should characterize:

- cellular antennas;
- small-cell networks;
- antenna density;
- beamforming and changing beam direction;
- multiple cellular generations operating simultaneously;
- infrastructure near homes and schools;
- cumulative exposure from multiple nearby sites; and
- changes in exposure as network traffic and infrastructure configurations change.

Onsite measurements are particularly important. ICNIRP notes that personal exposure from base stations is influenced by antenna height, orientation, tilt, direction, surrounding structures, vegetation, distance, and other factors, and that onsite field measurements are the most accurate way to assess actual exposure.

9. Research on reproductive, developmental, and multigenerational effects

Given the importance of reproductive health and early development, research should specifically examine:

- sperm count and motility;
- reproductive hormones;
- ovarian and testicular function;
- pregnancy outcomes;
- fetal development;
- birth outcomes;
- neurodevelopment;
- childhood development; and
- potential effects across generations.

Studies should include exposure during different developmental windows rather than treating pregnancy, infancy, childhood, and adulthood as equivalent exposure conditions.

NIH's current NICHD research priorities already emphasize pregnancy, reproductive health, child development, and the need for research specifically addressing populations such as pregnant women and children.

10. Environmental and ecological effects

Federal research should not be limited to human health.

Research should examine potential effects of RF/EMF exposure on:

- insects and pollinators;
- birds;
- mammals;
- livestock;
- plants;
- aquatic organisms; and
- ecosystems.

Studies should include realistic environmental exposures, long-term exposure, reproductive and developmental endpoints, behavior, navigation, population-level effects, and interactions involving multiple environmental stressors.

This is an emerging research area internationally. ICNIRP currently has a dedicated working group examining environmental effects of EMFs and whether human exposure guidelines are sufficiently protective for plants and animals in their natural environment.

11. Research on newer and rapidly changing technologies

Research should occur ahead of, rather than years after, widespread deployment of new wireless technologies.

Priority areas should include:

- 5G;
- emerging 6G technologies;
- millimeter-wave and higher-frequency systems;
- advanced beamforming;
- dense small-cell networks;
- satellite communications;
- IoT;
- wearable technologies;
- wireless power-transfer systems;
- connected vehicles and autonomous vehicles;
- smart-home systems; and
- future communication technologies not yet widely deployed.

Research should characterize both the exposure patterns and potential health implications of these technologies before exposure becomes ubiquitous.

12. Research on people reporting symptoms associated with EMF/RF exposure

Federal research should also investigate people who report symptoms that they associate with EMF/RF exposure.

Research should use objective exposure measurements and controlled study designs to examine reported outcomes such as headaches, sleep disturbance, fatigue, cognitive difficulties, dizziness, palpitations, and other symptoms.

The goal should be to determine whether particular exposure characteristics, environments, individual factors, or combinations of factors are associated with these reports, while avoiding assumptions about the cause of symptoms before the evidence is established.

13. Research on vulnerable and medically complex populations

Research should include people who may have different exposure circumstances or biological considerations, including:

- people with implanted medical devices;

- people using multiple electronic medical devices;
- older adults;
- people with occupational RF exposure;
- people living or working very close to wireless infrastructure; and
- individuals with substantial cumulative exposure from multiple wireless technologies.

For implanted medical devices, research should distinguish electromagnetic interference and device-function effects from potential biological effects of RF exposure itself.

14. Development of a national RF/EMF exposure surveillance system

Perhaps the most important infrastructure gap is the absence of a comprehensive national system for tracking actual RF/EMF exposure. Cellular towers and other fixed wireless infrastructure should have embedded emission/transmission warning or alert management systems that address actual emissions from the whole cluster and individual transmitters that are found to be out of expected ranges. These clustered systems should be required to notify federal reporting systems. The Federal reporting systems should be responsible to monitor systematic issues, ensure faulty systems are corrected, and openly with transparency ensure the public is aware of these incidents.

Federal agencies should establish a coordinated national program that collects standardized exposure measurements from:

- homes;
- schools;
- childcare facilities;
- healthcare facilities;
- workplaces;
- residential areas;
- public spaces;
- agricultural settings; and
- locations near significant wireless infrastructure.

Measurements should be repeatable over time so that changes in infrastructure, technology, and network activity can be tracked.

The resulting exposure database could then be linked, with appropriate privacy protections, to epidemiological and public-health data.

This would allow researchers to study actual exposure rather than relying primarily on estimates based on device ownership, distance, or modeled infrastructure characteristics.

15. Independent, long-term federal research infrastructure

Finally, I believe the federal government should establish a sustained, independently administered RF/EMF research program rather than relying primarily on short-term studies conducted in response to individual technologies or regulatory questions.

The program should include appropriate federal agencies, with coordination across epidemiology, environmental health, toxicology, dosimetry, engineering, neuroscience, reproductive health, developmental biology, and ecology.

Research funding should support both studies that identify potential adverse effects and studies that do not find adverse effects. Independence, transparency of funding and methodology, preregistration where appropriate, replication of important findings, standardized exposure protocols, and public availability of research data and methods should be emphasized.

Q17: How can federal health agencies improve coordination of EMF and RF radiation research? Please comment on potential roles for federal health agencies including, but not limited to:

Federal health agencies could substantially improve EMF and RF research by establishing a coordinated, long-term federal research framework rather than having individual agencies address separate aspects of the issue in isolation.

The research questions involve environmental health, toxicology, epidemiology, exposure science, engineering, medical devices, occupational health, developmental health, and public-health surveillance. No single agency has responsibility or expertise for all of these areas.

HHS should establish a **formal cross-agency RF/EMF research and surveillance program** rather than relying on individual agencies to coordinate informally.

The agencies should maintain a **shared national RF/EMF research agenda and research-gap database** so that studies funded by one agency build on, rather than duplicate, work supported by another.

I would also recommend a common federal RF/EMF data standard. Research and surveillance programs should use compatible definitions and reporting requirements for frequency, field strength, power density, SAR, modulation, duty cycle, duration, distance, source, location, and simultaneous exposure.

I believe an important issue that federal agencies should address is not only the integrity of research **after it has been funded**, but the possibility of bias in determining **which research questions receive funding in the first place**.

This distinction is important.

Scientific-integrity policies can protect the publication and communication of research that has already been conducted. However, they do not by themselves address a more fundamental potential problem: **research questions that are never adequately funded or pursued because their potential findings could have significant economic or regulatory consequences.**

RF and wireless communications are major and rapidly expanding industries. Research that identifies previously unrecognized health or environmental risks could potentially result in additional testing requirements, changes to exposure standards, product modifications, infrastructure changes, consumer disclosures, delays in product deployment, or other regulatory requirements.

Those potential consequences create an important reason for federal research to be structured so that **economic or regulatory implications do not determine which scientifically credible questions are considered worthy of investigation.**

I believe the federal research system should recognize and protect against this possibility that federal agencies or individual researchers intentionally suppress research because it could be unfavorable to industry as a matter of research governance.

For example, research should be eligible for federal support when it investigates:

- potential effects below current exposure limits;
- limitations of SAR as a measure of real-world cumulative exposure;
- long-term exposure;
- simultaneous exposure from multiple RF sources;
- children and developing populations;
- pregnancy and fetal exposure;
- reproductive and developmental outcomes;
- biological effects that do not depend on measurable tissue heating;
- exposure from cellular infrastructure and small-cell networks;
- environmental and ecological effects;
- newer frequencies and modulation characteristics;
- emerging wireless technologies for which long-term evidence does not yet exist; and
- findings that have not yet been adequately replicated.

The fact that a finding could potentially lead to additional regulation should not be a reason to avoid asking the question. Additionally, federal agencies should make the RF/EMF research portfolio itself transparent. This would make it possible to evaluate whether the overall research portfolio provides a balanced examination of the scientific questions, rather than simply evaluating the integrity of individual studies.

Technological development occurs much faster than the time required to conduct long-term epidemiological research, establish biological evidence, evaluate cumulative exposure, and develop or revise regulations. By the time sufficient evidence exists to answer a question

conclusively, a technology may already be widespread. Where there is substantial uncertainty about a new exposure pattern, federal agencies should be willing to state openly:

We do not yet know.

That statement should not be treated as evidence that a technology is unsafe. It is an acknowledgment that the scientific evidence is incomplete.

Likewise, the absence of definitive evidence of harm should not automatically be communicated as though the relevant question has been conclusively resolved.

I also believe federal health agencies should be more comfortable issuing appropriately worded precautionary statements when important questions remain unresolved.

A precautionary statement can simply acknowledge that a particular exposure scenario has not been adequately studied and that reasonable measures may be available to reduce unnecessary exposure while research continues.

For example, where evidence is insufficient to characterize long-term exposure of children in a particular environment, an agency could acknowledge that limitation rather than implying that adult-based testing has completely answered the question.

Similarly, where cumulative exposure from multiple simultaneous wireless sources has not been adequately characterized, agencies should acknowledge that limitation rather than treating compliance of individual devices as though it completely describes the person's total exposure.

Q18: Please identify any additional scientific evidence, technical information, data, or recommendations that federal health agencies should consider when evaluating potential adverse health effects associated with RF/EMF radiation exposure.

I respectfully ask that HHS consider the recommendations throughout this response. Because the questions and scientific studies applied to multiple questions and topics I am providing a summarized list of relevant scientific studies and papers that support the requested topics/questions:

Q5 References: REF-0021, REF-0028, REF-0033, REF-0038, REF-0040, REF-0047, REF-0048, REF-0050, REF-0059, REF-0061, REF-0070, REF-0089, REF-0098, REF-0111, REF-0117, REF-0118, REF-0120, REF-0122, REF-0142, REF-0144, REF-0165, REF-0174, REF-0176

Q6 References: REF-0001, REF-0003, REF-0028, REF-0032, REF-0038, REF-0046, REF-0057, REF-0058, REF-0060, REF-0065, REF-0072, REF-0076, REF-0082, REF-0102, REF-0106, REF-0107, REF-0122, REF-0133, REF-0144, REF-0151, REF-0152, REF-0156, REF-0159, REF-0166, REF-0174, REF-0175, REF-0176

Q7 References: REF-0021, REF-0028, REF-0033, REF-0038, REF-0040, REF-0047, REF-0048, REF-0050, REF-0059, REF-0061, REF-0070, REF-0089, REF-0098, REF-0111,

REF-0117, REF-0118, REF-0120, REF-0122, REF-0142, REF-0144, REF-0165, REF-0174, REF-0176

Q8 References: REF-0021, REF-0028, REF-0033, REF-0038, REF-0040, REF-0047, REF-0048, REF-0050, REF-0059, REF-0061, REF-0070, REF-0089, REF-0098, REF-0111, REF-0117, REF-0118, REF-0120, REF-0142, REF-0144, REF-0165, REF-0176

Q9 References: REF-0009, REF-0011, REF-0086, REF-0087, REF-0091, REF-0150

Q10 References: REF-0018, REF-0064, REF-0087, REF-0148

Q11 References: REF-0001, REF-0003, REF-0005, REF-0007, REF-0013, REF-0014, REF-0017, REF-0024, REF-0025, REF-0028, REF-0031, REF-0032, REF-0035, REF-0038, REF-0039, REF-0040, REF-0041, REF-0042, REF-0043, REF-0045, REF-0046, REF-0051, REF-0052, REF-0053, REF-0054, REF-0056, REF-0057, REF-0058, REF-0060, REF-0065, REF-0066, REF-0073, REF-0074, REF-0076, REF-0078, REF-0081, REF-0082, REF-0084, REF-0088, REF-0090, REF-0093, REF-0095, REF-0097, REF-0098, REF-0100, REF-0101, REF-0102, REF-0103, REF-0104, REF-0107, REF-0108, REF-0109, REF-0110, REF-0112, REF-0113, REF-0114, REF-0115, REF-0116, REF-0119, REF-0120, REF-0121, REF-0122, REF-0129, REF-0130, REF-0131, REF-0133, REF-0134, REF-0135, REF-0136, REF-0139, REF-0145, REF-0149, REF-0151, REF-0152, REF-0154, REF-0156, REF-0157, REF-0158, REF-0159, REF-0160, REF-0161, REF-0162, REF-0163, REF-0164, REF-0166, REF-0167, REF-0168, REF-0169, REF-0170, REF-0174, REF-0175, REF-0176, REF-0177

Q12 References: REF-0001, REF-0002, REF-0003, REF-0005, REF-0006, REF-0007, REF-0008, REF-0009, REF-0010, REF-0011, REF-0012, REF-0013, REF-0014, REF-0015, REF-0016, REF-0017, REF-0018, REF-0020, REF-0021, REF-0022, REF-0023, REF-0024, REF-0025, REF-0026, REF-0028, REF-0029, REF-0030, REF-0031, REF-0032, REF-0033, REF-0034, REF-0035, REF-0036, REF-0037, REF-0038, REF-0039, REF-0040, REF-0041, REF-0042, REF-0043, REF-0044, REF-0045, REF-0046, REF-0047, REF-0048, REF-0049, REF-0050, REF-0051, REF-0052, REF-0053, REF-0054, REF-0055, REF-0056, REF-0057, REF-0058, REF-0059, REF-0060, REF-0061, REF-0062, REF-0063, REF-0064, REF-0065, REF-0066, REF-0067, REF-0068, REF-0069, REF-0070, REF-0071, REF-0072, REF-0073, REF-0074, REF-0075, REF-0076, REF-0077, REF-0078, REF-0079, REF-0080, REF-0081, REF-0082, REF-0084, REF-0085, REF-0086, REF-0087, REF-0088, REF-0089, REF-0090, REF-0091, REF-0092, REF-0093, REF-0094, REF-0095, REF-0096, REF-0097, REF-0098, REF-0100, REF-0101, REF-0102, REF-0103, REF-0104, REF-0105, REF-0106, REF-0107, REF-0108, REF-0109, REF-0110, REF-0111, REF-0112, REF-0113, REF-0114, REF-0115, REF-0116, REF-0117, REF-0118, REF-0119, REF-0120, REF-0121, REF-0122, REF-0123, REF-0124, REF-0125, REF-0126, REF-0127, REF-0128, REF-0129, REF-0130, REF-0131, REF-0132, REF-0133, REF-0134, REF-0135, REF-0136, REF-0137, REF-0138, REF-0139, REF-0140, REF-0141, REF-0142, REF-0143, REF-0144, REF-0145, REF-0146, REF-0147, REF-0148, REF-0149, REF-0150, REF-0151, REF-0152, REF-0153, REF-0154, REF-0156, REF-0157, REF-0158, REF-0159, REF-0160, REF-0161, REF-0162, REF-0163, REF-0164, REF-0165, REF-0166, REF-0167, REF-0168, REF-0169, REF-0170, REF-0171, REF-0173, REF-0174, REF-0175, REF-0176, REF-0177

Q13 References: REF-0001, REF-0002, REF-0003, REF-0005, REF-0006, REF-0007, REF-0008, REF-0009, REF-0011, REF-0013, REF-0014, REF-0015, REF-0017, REF-0018, REF-0020, REF-0021, REF-0022, REF-0023, REF-0024, REF-0025, REF-0028, REF-0029,

REF-0030, REF-0031, REF-0032, REF-0033, REF-0034, REF-0035, REF-0036, REF-0037, REF-0038, REF-0039, REF-0040, REF-0041, REF-0042, REF-0043, REF-0044, REF-0045, REF-0046, REF-0047, REF-0048, REF-0049, REF-0050, REF-0051, REF-0052, REF-0053, REF-0054, REF-0055, REF-0056, REF-0057, REF-0058, REF-0059, REF-0060, REF-0061, REF-0062, REF-0063, REF-0064, REF-0065, REF-0066, REF-0067, REF-0068, REF-0070, REF-0071, REF-0073, REF-0074, REF-0075, REF-0076, REF-0077, REF-0078, REF-0079, REF-0080, REF-0081, REF-0082, REF-0084, REF-0085, REF-0087, REF-0088, REF-0089, REF-0090, REF-0091, REF-0093, REF-0094, REF-0095, REF-0097, REF-0098, REF-0100, REF-0101, REF-0102, REF-0103, REF-0104, REF-0105, REF-0107, REF-0108, REF-0109, REF-0110, REF-0111, REF-0112, REF-0113, REF-0114, REF-0115, REF-0116, REF-0117, REF-0118, REF-0119, REF-0120, REF-0121, REF-0122, REF-0123, REF-0124, REF-0125, REF-0126, REF-0127, REF-0128, REF-0129, REF-0130, REF-0131, REF-0132, REF-0133, REF-0134, REF-0135, REF-0136, REF-0139, REF-0140, REF-0141, REF-0142, REF-0143, REF-0144, REF-0145, REF-0147, REF-0148, REF-0149, REF-0150, REF-0151, REF-0152, REF-0154, REF-0156, REF-0157, REF-0158, REF-0159, REF-0160, REF-0161, REF-0162, REF-0163, REF-0164, REF-0165, REF-0166, REF-0167, REF-0168, REF-0169, REF-0170, REF-0173, REF-0174, REF-0175, REF-0176, REF-0177

Q15 References: REF-0002, REF-0006, REF-0009, REF-0010, REF-0011, REF-0012, REF-0015, REF-0016, REF-0021, REF-0022, REF-0023, REF-0026, REF-0028, REF-0033, REF-0037, REF-0038, REF-0047, REF-0050, REF-0059, REF-0061, REF-0068, REF-0069, REF-0070, REF-0077, REF-0080, REF-0086, REF-0087, REF-0089, REF-0091, REF-0092, REF-0096, REF-0105, REF-0111, REF-0118, REF-0120, REF-0122, REF-0124, REF-0125, REF-0126, REF-0127, REF-0128, REF-0137, REF-0138, REF-0142, REF-0143, REF-0144, REF-0146, REF-0147, REF-0150, REF-0153, REF-0165, REF-0171, REF-0173

Q16 References: REF-0001, REF-0002, REF-0003, REF-0005, REF-0006, REF-0007, REF-0008, REF-0009, REF-0010, REF-0011, REF-0012, REF-0013, REF-0014, REF-0015, REF-0016, REF-0017, REF-0018, REF-0020, REF-0021, REF-0022, REF-0023, REF-0024, REF-0025, REF-0026, REF-0028, REF-0029, REF-0030, REF-0031, REF-0032, REF-0033, REF-0034, REF-0035, REF-0036, REF-0037, REF-0038, REF-0039, REF-0040, REF-0041, REF-0042, REF-0043, REF-0044, REF-0045, REF-0046, REF-0047, REF-0049, REF-0050, REF-0051, REF-0052, REF-0053, REF-0054, REF-0055, REF-0056, REF-0057, REF-0058, REF-0059, REF-0060, REF-0061, REF-0062, REF-0063, REF-0064, REF-0065, REF-0066, REF-0067, REF-0068, REF-0069, REF-0070, REF-0071, REF-0072, REF-0073, REF-0074, REF-0075, REF-0076, REF-0077, REF-0078, REF-0079, REF-0080, REF-0081, REF-0082, REF-0084, REF-0085, REF-0086, REF-0087, REF-0088, REF-0089, REF-0090, REF-0091, REF-0092, REF-0093, REF-0094, REF-0095, REF-0096, REF-0097, REF-0098, REF-0100, REF-0101, REF-0102, REF-0103, REF-0104, REF-0105, REF-0106, REF-0107, REF-0108, REF-0109, REF-0110, REF-0111, REF-0112, REF-0113, REF-0114, REF-0115, REF-0116, REF-0117, REF-0118, REF-0119, REF-0120, REF-0121, REF-0122, REF-0123, REF-0124, REF-0125, REF-0126, REF-0127, REF-0128, REF-0129, REF-0130, REF-0131, REF-0132, REF-0133, REF-0134, REF-0135, REF-0136, REF-0137, REF-0138, REF-0139, REF-0140, REF-0141, REF-0142, REF-0143, REF-0144, REF-0145, REF-0146, REF-0147, REF-0148, REF-0149, REF-0150, REF-0151, REF-0152, REF-0153, REF-0154, REF-0156, REF-0157, REF-0158, REF-0159, REF-0160, REF-0161, REF-0162, REF-0163, REF-0164, REF-0165,

REF-0166, REF-0167, REF-0168, REF-0169, REF-0170, REF-0171, REF-0173, REF-0174, REF-0175, REF-0176, REF-0177

Q17 References: REF-0004, REF-0172

Q18 References: REF-0004, REF-0172

REF-0001. 45 GHz Microwave Radiation Impairs Learning and Spatial Memory via Oxidative/Nitrosative Stress Induced p53-Dependent/Independent Hippocampal Apoptosis: Molecular Basis and Underlying Mechanism. Shahin, S., et al. Toxicological Sciences 148(2):380-399. (2015).

****FCC Topic:**** Long-term/biological effects (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** 45 GHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=45+GHz+Microwave+Radiation+Impairs+Learning+and+Spatial+Memory+via+Oxidative%2FNitrosative+Stress+Induced+p53-Dependent%2FIndependent+Hippocampal+Apoptosis%3A+Molecular+Basis+and+Underlying+Mechanism>

REF-0002. 47 CFR § 1.1307 — Actions That May Have a Significant Environmental Effect, for Which Environmental Assessments Must Be Prepared. Federal Communications Commission (FCC). Code of Federal Regulations, Title 47, § 1.1307.

****FCC Topic:**** RF exposure evaluation / fixed transmitters / regulatory compliance and mitigation.

****HHS Questions:**** Q15, Q16; also relevant to Q12 and Q13.

****Dated:**** Current regulation; consult the linked version for the applicable text.

****Exposure:**** RF emissions from FCC-regulated facilities and equipment subject to environmental review and RF exposure evaluation requirements.

****Finding:**** Establishes regulatory procedures for identifying facilities and actions that require environmental assessment, including RF exposure evaluation in applicable circumstances. It provides a regulatory foundation for considering additional verification, escalation, and documented corrective action where compliance concerns arise. Limitation: Applicability depends on the specific rule provisions and circumstances. The regulation does not create a universal requirement for continuous RF field monitoring, automatic federal alerts, or public reporting of every operational anomaly.

****Link:**** <https://www.law.cornell.edu/cfr/text/47/1.1307>

REF-0003. A Prospective Cohort Study of Adolescents' Memory Performance and Individual Brain Dose of Microwave Radiation from Wireless Communication. Foerster, M., et al. Environmental Health Perspectives 126(7). (2018).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Real-world ubiquity/use conditions (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=A+Prospective+Cohort+Study+of+Adolescents%E2%80%99+Memory+Performance+and+Individual+Brain+Dose+of+Microwave+Radiation+from+Wireless+Communication>

REF-0004. A Review of the Ecological Effects of Radiofrequency Electromagnetic Fields (RF-EMF). Cucurachi, S., et al. Environment International 51:116–140. (2013).

****FCC Topic:**** Environmental effects of RF exposure.

****HHS Questions:**** Q17, Q18

****Dated:**** 2013.

****Exposure:**** RF-EMF affecting plants, animals, and ecosystems.

****Finding:**** Reviews experimental evidence concerning ecological effects and identifies limitations in exposure standardization and the relative lack of field and ecosystem-level studies.

****Link:**** <https://doi.org/10.1016/j.envint.2012.10.009>

REF-0005. A Review on Electromagnetic Fields (EMFs) and the Reproductive System. Asghari, A., et al. *Electronic Physician Journal* 8(7):2655-2662. (2016).

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2016

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=A+Review+on+Electromagnetic+Fields+%28EMFs%29+and+the+Reproductive+System>

REF-0006. About the Effects of Microwave Exposure from Cellular Phone Base Stations: A First Approach. Navarro, E. A., Segura, J., Gómez-Perretta, C., Portolés, M., Maestu, C., & Bardasano, J. L. (publication year and journal details should be checked against the linked paper).

****FCC Topic:**** RF exposure near base stations / reported symptoms / exposure measurement.

****HHS Questions:**** Q12, Q13, Q15, Q16.

****Dated:**** Verify publication year.

****Exposure:**** Reported RF power density in residences near cellular base stations; the supplied summary gives 100–1,100 $\mu\text{W}/\text{m}^2$.

****Finding:**** Examined statistical relationships between measured or estimated residential RF exposure and reported symptoms. Limitation: The paper describes an exploratory analysis; reported associations cannot establish causation and may be affected by sample size, exposure assessment, confounding, and symptom-reporting methods.

****Link:****

https://www.researchgate.net/profile/Ceferino-Maestu/publication/253809193_About_the_effects_of_microwave_exposure_from_cellular_phone_base_stations_A_first_approach/links/02e7e5296f09519c5c000000/About-the-effects-of-microwave-exposure-from-cellular-phone-base-stations-A-first-approach.pdf

REF-0007. Aloe Arborescens Juice Prevents EMF-Induced Oxidative Stress and Thus Protects from Pathophysiology in the Male Reproductive System In Vitro. Solek, P., et al. *Environmental Research* 166:141-149. (2018).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Aloe+Arborescens+Juice+Prevents+EMF-Induced+Oxidative+Stress+and+Thus+Protects+from+Pathophysiology+in+the+Male+Reproductive+System+In+Vitro>

REF-0008. Analysis of the Impact of Mobile Phones on Male Sperm Infertility. Kibona, L. (2013). Research paper.

****FCC Topic:**** RF exposure / male reproductive health / fertility.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2013.

****Exposure:**** The paper describes analysis of exposure from mobile phones operating at 900 and 1,800 MHz near the male reproductive organs; the supplied summary reports 1,700–10,000 $\mu\text{W}/\text{m}^2$.

****Finding:**** Investigates whether mobile-phone RF exposure may affect male reproductive function and sperm-related outcomes.

****Link:****

<https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=ca633c66f058c44b5f6e7031ffc678be41055ccd>

REF-0009. Assessment of EMF Human Exposure Levels Due to Wearable Antennas at 5G Frequency Band. Piro, G., et al. Sensors 23(1):390. (2023).

****FCC Topic:**** Wearable 5G devices / exposure assessment.

****HHS Questions:**** Q9, Q12, Q13, Q15, Q16

****Dated:**** 2023.

****Exposure:**** Approximately 3.5 GHz and 26.5 GHz wearable antennas positioned on the trunk.

****Finding:**** Modeled exposure was concentrated primarily in superficial tissue immediately beneath the antenna, with exposure distributions changing with antenna position and distance from the body.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Assessment+of+EMF+Human+Exposure+Levels+Due+to+Wearable+Antennas+at+5G+Frequency+Band>

REF-0010. Assessment of Human Exposure to EMF from 5G Base Stations: Analysis, Evaluation and Comparison of Different Assessment Methods. Expósito, N., et al. (2024).

****FCC Topic:**** 5G exposure assessment methodology.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** 2024.

****Exposure:**** RF fields from 5G base stations.

****Finding:**** Compared broadband field probes, spectrum analyzers, and drive-test scanners and demonstrated that measurement methodology and variations in signal levels are important when characterizing exposure from 5G infrastructure.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Assessment+of+Human+Exposure+to+EMF+from+5G+Base+Stations>

REF-0011. Assessment of Human Exposure to Radiofrequency Electromagnetic Fields from Wireless Communication Devices Operating Close to the Human Body. ITU-T K.160. International Telecommunication Union. (2025).

****FCC Topic:**** Exposure assessment from body-worn and close-proximity wireless devices.

****HHS Questions:**** Q9, Q12, Q13, Q15, Q16

****Dated:**** 2025.

****Exposure:**** Wireless communication devices operating next to or against the human body.

****Finding:**** Addresses device category, usage position, frequency, power, operating mode, measurement distance, simultaneous transmission, and total exposure ratio; includes limb-worn devices, clothing-integrated devices, body-worn accessories, and devices used next to or against the body.

****Link:**** <https://www.itu.int/rec/T-REC-K.160>

REF-0012. Assessment of Radio Frequency Fields in the 2.45 GHz Band Produced by Smart Home Devices. McKenzie, R., et al. (2024).

****FCC Topic:**** Smart-home devices / real-world RF exposure.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** 2024.

****Exposure:**** 2.45 GHz RF fields from Wi-Fi- and Bluetooth-connected smart-home devices.

****Finding:**** Measured RF fields under simulated high-activity conditions and examined transmission duty cycles, demonstrating the importance of measuring actual device transmission patterns rather than assuming that connected devices transmit continuously.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Assessment+of+Radio+Frequency+Fields+in+the+2.45+GHz+Band+Produced+by+Smart+Home+Devices>

REF-0013. Associations of Maternal Cell Phone Use During Pregnancy, Pregnancy Duration And Fetal Growth In Four Birth Cohorts. Tsarna, E., et al. American Journal of Epidemiology 188(7):1270-1280. (2019).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2019

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:**** <https://doi.org/10.1093/aje/kwz005>

REF-0014. Autism-Relevant Social Abnormalities in Mice Exposed Perinatally to Extremely Low Frequency Electromagnetic Fields. Alsaeed, I., et al. International Journal of Developmental Neuroscience 37:58-64. (2014).

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2014

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Autism-Relevant+Social+Abnormalities+in+Mice+Exposed+Perinatally+to+Extremely+Low+Frequency+Electromagnetic+Fields>

REF-0015. Base Stations — RF Exposure Assessment and Measurement. International Commission on Non-Ionizing Radiation Protection (ICNIRP). (n.d.). ICNIRP: Base Stations.

****FCC Topic:**** Fixed wireless infrastructure / site-specific exposure / compliance assessment.

****HHS Questions:**** Q15, Q16; also relevant to Q12 and Q13.

****Dated:**** Undated webpage; access; October 10, 2026.

****Exposure:**** RF electromagnetic fields from cellular base stations and other fixed transmitting antennas, including the effects of antenna orientation, height, tilt, reflections, vegetation, and surrounding conditions.

****Finding:**** ICNIRP explains that onsite field measurements provide the most accurate assessment of actual exposure in a particular environment and that exposure depends on site-specific conditions. This supports evaluating real operating conditions rather than relying exclusively on distance from an antenna or predicted exposure.

****Link:**** <https://www.icnirp.org/en/applications/base-stations/index.html>

REF-0016. Base Stations. International Commission on Non-Ionizing Radiation Protection (ICNIRP).

****FCC Topic:**** Infrastructure exposure assessment / proximity to wireless installations.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** Current guidance.

****Exposure:**** RF emissions from base stations.

****Finding:**** ICNIRP explains that personal exposure is most accurately assessed through onsite field measurements and that antenna height, tilt, direction, vegetation, reflections, and distance can affect measured exposure. Distance alone is therefore not a reliable proxy for exposure.

****Link:**** <https://www.icnirp.org/en/rf-faqs/index.html>

REF-0017. Bektas, H., Bektas, M. S., & Dasdag, S., Effect of mobile phone usage duration during pregnancy on the general motor movements of infants. Biotechnology & Biotechnological Equipment, 36(1), 57–67. (2022)

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2022

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/?term=Bektas%2C+H>

REF-0018. Bibliography of Reported Biological Phenomena ("Effects") and Clinical Manifestations Attributed to Microwave and Radio-Frequency Radiation. Glaser, Z. R. (1972). Defense Documentation Center / Defense Technical Information Center (DTIC), Report AD0750271. Prepared at the Naval Medical Research Institute, Bethesda, Maryland.

****FCC Topic:**** Historical RF and microwave bioeffects research / reported clinical manifestations / research gaps and evidence evaluation.

****HHS Questions:**** Q10, Q12, Q13, Q16.

****Dated:**** April 20, 1972.

****Exposure:**** Bibliographic compilation of more than 2,300 references on biological responses to radiofrequency and microwave radiation published through April 1972, with particular attention to effects reported in humans and detailed inclusion of Soviet and Eastern European literature.

****Finding:**** Provides an extensive historical bibliography of reported biological phenomena and clinical manifestations attributed to RF and microwave exposure. Chapter 1 outlines effects reported in the literature; the remaining citations are arranged alphabetically by author to facilitate retrieval of the original publications. The report is useful for identifying early research, historical hypotheses, and studies that may warrant examination in the context of later evidence. Limitation: This is a bibliography and literature compilation, not a systematic review using modern evidence-grading methods. Inclusion of a reported effect or study does not establish that the effect was independently replicated, that exposure caused it, or that the reported exposure conditions are comparable to modern environmental RF exposure. Its coverage ends in April 1972 and must be supplemented with later research.

****Link:**** https://archive.org/details/DTIC_AD0750271

REF-0019. Blood–brain barrier and cardiovascular outcomes

REF-0020. Blood–Brain Barrier Permeability Following RF Exposure. Persson, B. R. R., et al. (2009). Electromagnetic Biology and Medicine.

****FCC Topic:**** RF exposure / neurological mechanisms / blood–brain barrier.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2009.

****Exposure:**** The linked paper concerns electromagnetic exposure and blood–brain barrier permeability; the supplied summary reports 10,000 $\mu\text{W}/\text{m}^2$.

****Finding:**** Examines whether exposure can alter blood–brain barrier permeability under experimental conditions.

****Link:**** <https://www.tandfonline.com/doi/abs/10.1080/15368370802344037>

REF-0021. Building Science and Radiofrequency Radiation: What Makes Smart and Healthy Buildings. Clegg, F., et al. Building and Environment 176(106324):1-15. (2020).

****FCC Topic:**** Real-world ubiquity/use conditions (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2020

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Building+Science+and+Radiofrequency+Radiation%3A+What+Makes+Smart+and+Healthy%2%A0+Buildings>

REF-0022. Cancer Incidence and Mortality and Proximity to TV Towers. Hocking, B., Gordon, I. R., Grain, H. L., & Hatfield, G. E. (1996). Medical Journal of Australia, 165(11–12), 601–605.

****FCC Topic:**** RF exposure from broadcast transmitters / childhood leukemia / cancer outcomes.

****HHS Questions:**** Q12, Q13, Q15, Q16.

****Dated:**** 1996.

****Exposure:**** Residence in areas at different distances from television towers in northern Sydney; the supplied summary reports 2,000–80,000 $\mu\text{W}/\text{m}^2$.

****Finding:**** The study reported an association between residence nearer television towers and increased childhood leukemia incidence and mortality. Limitation: The study compared geographic areas and did not establish each child's actual RF exposure. Its findings demonstrate an association, not proof that RF caused leukemia.

****Link:**** <https://onlinelibrary.wiley.com/doi/abs/10.5694/j.1326-5377.1996.tb138661.x>

REF-0023. Cancer Incidence near Radio and Television Transmitters in Great Britain. I. Sutton Coldfield Transmitter. Dolk, H., Shaddick, G., Walls, P., Grundy, C., Thakrar, B., Kleinschmidt, I., & Elliott, P. (1997). *American Journal of Epidemiology*, 145(1), 1–9.

****FCC Topic:**** RF exposure from broadcast transmitters / adult leukemia / environmental epidemiology.

****HHS Questions:**** Q12, Q13, Q15, Q16.

****Dated:**** 1997.

****Exposure:**** Residential proximity to a high-power radio/television transmitter, with exposure estimated geographically rather than through personal RF monitoring. The supplied summary reports 13,000–57,000 $\mu\text{W}/\text{m}^2$.

****Finding:**** The study reported spatial patterns in cancer incidence near the Sutton Coldfield transmitter, including findings involving adult leukemia. Limitation: This was an ecological/geographical study; proximity-based exposure estimates cannot establish individual exposure or causation, and findings from one transmitter area may not generalize to other locations.

****Link:**** <https://academic.oup.com/aje/article-abstract/145/1/1/68115>

REF-0024. Cell Phones and Male Infertility: Dissecting the Relationship. Deepinder, F., et al. *Reproductive BioMedicine Online* 15(3):266-270. (2007).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2007

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Cell+Phones+and+Male+Infertility%3A+Dissecting+the+Relationship>

REF-0025. Cell Phones: Modern Man's Nemesis? Makker, K., et al. *Reproductive BioMedicine Online* 18(1):148-157. (2009).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2009

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Cell+Phones%3A+Modern+Man%E2%80%99s+Nemesis%3F+Makker%2C+K>

REF-0026. Characterization of Radiofrequency Field Emissions from Smart Meters. Tell, R.A., Kavet, R. & Mezei, G. (2013).

****FCC Topic:**** Wireless infrastructure / smart-meter exposure characterization.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** 2013.

****Exposure:**** RF emissions from smart meters.

****Finding:**** Measured emissions from smart meters operating in northern California and examined transmission patterns, utility transmission data, and duty cycles.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Characterization+of+Radiofrequency+Field+Emissions+from+Smart+Meters>

REF-0027. Childhood development, leukemia, and cancer

REF-0028. Children Absorb Higher Doses of Radio Frequency Electromagnetic Radiation From Mobile Phones Than Adults. Morris, R., et al. IEEE Access: The Journal for Rapid Open Access Publishing Doi: 10.1109/ACCESS.2015.2478701. (2015).

****FCC Topic:**** Children/developmental exposure (Other health effects); Long-term/biological effects; Children/developmental exposure (Cancer and Reproductive)

****HHS Questions:**** Q5, Q6, Q7, Q8, Q11, Q12, Q13, Q15, Q16

****Dated:**** 2015

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:**** <https://doi.org/10.1109/ACCESS.2015.2478701>

REF-0029. Children's Exposure to RF Sources and Reported Health Symptoms. Durusoy, R., et al. (2017). Environmental Health.

****FCC Topic:**** Children's exposure / headaches / irritability / behavior and concentration.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2017.

****Exposure:**** Study of children aged 8–17 and reported exposure to RF sources; exact exposure measures should be confirmed in the full paper.

****Finding:**** Investigated associations between RF exposure indicators and reported symptoms, including headache, irritability, and concentration or behavioral difficulties. Limitation: Observational associations and self-reported symptoms cannot demonstrate causation; the study's exposure assessment and potential confounders must be considered.

****Link:**** <https://link.springer.com/article/10.1186/s12940-017-0257-x>

REF-0030. Chromatin and DNA-Related Effects of Radiofrequency Electromagnetic Fields. Belyaev, I. (2008). Bioelectromagnetics.

****FCC Topic:**** RF exposure / genetic and cellular endpoints / biological mechanisms.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2008.

****Exposure:**** RF electromagnetic fields in laboratory studies; the supplied summary refers to changes in gene-related measures and chromatin condensation.

****Finding:**** Cited in research examining whether RF exposure can influence gene expression or other cellular and genetic endpoints.

****Link:**** <https://onlinelibrary.wiley.com/doi/abs/10.1002/bem.20445>

REF-0031. Chronic non-thermal exposure of modulated 2450 MHz microwave radiation alters thyroid hormones and behavior of male rats. Sinha, R.K. International Journal of Radiation Biology 84(6):505-513. (2008).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Reproductive)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2008

****Exposure:**** 2450 MHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Chronic+non-thermal+exposure+of+modulated+2450+MHz+microwave+radiation+alters+thyroid+hormones+and+behavior+of+male+rats>

REF-0032. Cognitive impairment and neurogenotoxic effects in rats exposed to low-intensity microwave radiation. Deshmukh, P.S., et al. International Journal of Toxicology 34(3):284-290. (2015).

****FCC Topic:**** Long-term/biological effects (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Cognitive+impairment+and+neurogenotoxic+effects+in+rats+exposed+to+low-intensity+microwave+radiation>

REF-0033. Commentary on the utility of the National Toxicology Program study on cell phone radiofrequency radiation data for assessing human health risks despite unfounded criticisms aimed at minimizing the findings of adverse health effects. Melnick, R. Environmental Research 168:1-6. (2019).

****FCC Topic:**** Long-term/biological effects (Cancer); Scientific evidence relevant to reassessment (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2019

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Commentary+on+the+utility+of+the+National+Toxicology+Program+study+on+cell+phone+radiofrequency+radiation+data+for+assessing+human+health+risks+despite+unfounded+criticisms+aimed+at+minimizing+the+findings+of+adverse+health+effects>

REF-0034. Comparing DNA Damage Induced by Mobile Telephony and Other Types of Man-Made Electromagnetic Fields. Panagopoulos, D. J. (2019). Mutation Research/Reviews in Mutation Research, 781, 53–62.

****FCC Topic:**** RF exposure / DNA damage / genetic mechanisms.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2019.

****Exposure:**** Review of research on DNA damage associated with mobile-telephony RF and other man-made electromagnetic fields.

****Finding:**** Reviews experimental findings and proposed mechanisms of DNA damage across different types of electromagnetic exposure. Limitation: This is a review, not a single exposure experiment; conclusions depend on the quality, consistency, and comparability of the studies included. The review covers more than RF alone, so its findings should not be generalized across all electromagnetic frequencies.

****Link:**** <https://www.sciencedirect.com/science/article/abs/pii/S1383574218300991>

REF-0035. Cranial and Postcranial Skeletal Variations Induced in Mouse Embryos by Mobile Phone Radiation. Fragopoulou, AF., et al. Pathophysiology 17(3):169-77. (2010).

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2010

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Cranial+and+Postcranial+Skeletal+Variations+Induced+in+Mouse+Embryos+by+Mobile+Phone+Radiation>

REF-0036. Cumulative RF Exposure, Stress Hormones, and Circadian Rhythms. Halgamuge, M. N. (2013). Publication details should be confirmed from the linked record.

****FCC Topic:**** RF exposure / stress response / sleep and circadian rhythms.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2013.

****Exposure:**** The supplied summary describes cumulative exposure and possible changes in stress hormones and circadian rhythms.

****Finding:**** Cited in the literature concerning biological responses to electromagnetic exposure and possible effects on stress-related processes.

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/23377737/>

REF-0037. Decreased Survival for Childhood Leukemia in Proximity to Television Towers. Hocking, B., & Gordon, I. (2003). Archives of Environmental Health, 58(9), 560–564.

****FCC Topic:**** Children's exposure / leukemia outcomes / survival.

****HHS Questions:**** Q12, Q13, Q15, Q16.

****Dated:**** 2003.

****Exposure:**** Residential proximity to television towers in Sydney. 2,000 -80,000 $\mu\text{W}/\text{m}^2$

****Finding:**** Follow-up research reported reduced survival among children with leukemia who lived nearer the towers. Limitation: The analysis concerned survival among diagnosed children and does not independently establish that RF exposure caused either leukemia or the observed survival differences.

****Link:**** <https://www.tandfonline.com/doi/abs/10.3200/AEOH.58.9.560-564>

REF-0038. Development of health-based exposure limits for radiofrequency radiation from wireless devices using a benchmark dose approach. Uche, U., et al. Environmental Health, 20(84). (2021).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization; Real-world ubiquity/use conditions (Cancer, Neurological/cognitive, reproductive); Real-world ubiquity/use conditions (Other health effects)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16; Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2021

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Development+of+health-based+exposure+limits+for+radiofrequency+radiation+from+wireless+devices+using+a+benchmark+dose+approach>

REF-0039. Different Periods of Intrauterine Exposure to Electromagnetic Field: Influence on Female Rats' Fertility, Prenatal and Postnatal Development. Alchalabi, A., et al. Asian Pacific Journal of Reproduction 5(1):14-23. (2015).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Different+Periods+of+Intrauterine+Exposure+to+Electromagnetic+Field%3A+Influence+on+Female+Rats%E2%80%99+Fertility%2C+Prenatal+and+Postnatal+Development>

REF-0040. Dosimetric Study of Fetal Exposure to Uniform Magnetic Fields at 50 Hz. Liorni, I., et al. Bioelectromagnetics 35(8):580-97 (2014).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16, Q5, Q7, Q8

****Dated:**** 2014

****Exposure:**** 50 Hz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Dosimetric+Study+of+Fetal+Exposure+to+Uniform+Magnetic+Fields+at+50%E2%80%89Hz>

REF-0041. Effect of Cell Phone Usage on Semen Analysis in Men Attending Infertility Clinic: An Observational Study. Agarwal, A., et al. Fertility and Sterility 89(1):124-128. (2008).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2008

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Effect+of+Cell+Phone+Usage+on+Semen+Analysis+in+Men+Attending+Infertility+Clinic%3A+An+Observational+Study>

REF-0042. Effect of Electromagnetic Field Exposure on the Reproductive System. Gye, M., et al. Journal of Clinical and Experimental Reproductive Medicine 39(1):1-19. (2012).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2012

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Effect+of+Electromagnetic+Field+Exposure+on+the+Reproductive+System>

REF-0043. Effect of mobile telephones on sperm quality: A systematic review and meta-analysis. Adams, J., et al. Environment International 70:106-112. (2014).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2014

****Exposure:**** Not stated in resource

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/24927498/>

REF-0044. Effect of Radiation Emitted by Wireless Devices on Male Reproductive Hormones: A Systematic Review. Maluin, S. M. M., Osman, K. O., Jaffar, F. H. F., & Ibrahim, S. F. (2021). Frontiers in Physiology, 12, 732420.

****FCC Topic:**** RF exposure / male reproductive health / evidence synthesis.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2021.

****Exposure:**** Animal and other research on RF-EMR from wireless devices, including mobile phones and Wi-Fi, and male reproductive hormones and testicular outcomes.

****Finding:**** Reviews studies reporting possible changes in testicular tissue, testosterone, and sperm parameters, while noting that conclusive evidence of harm to male reproductive hormones has not been established. Limitation: The review includes studies with varying designs and exposure methods.

****Link:**** <https://pmc.ncbi.nlm.nih.gov/articles/PMC8497974/>

REF-0045. Effect of radiofrequency radiation on reproductive health. Singh, R., et al. Indian Journal of Medical Research 148(Suppl 1): S92–S99. (2018).

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Effect+of+radiofrequency+radiation+on+reproductive+health>

REF-0046. Effects of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on microRNA expression in brain tissue. Dasdag, S., et al. International Journal of Radiation Biology 91(7):555-561. (2015).

****FCC Topic:**** Long-term/biological effects (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** 2.4 GHz

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/?term=Effects+of+2>

REF-0047. Effects of acute exposure to WIFI signals (2.45 GHz) on heart variability and blood pressure in Albinos rabbit. Saili, L., et al. Environmental Toxicology and Pharmacology. 40(2):600-605. (2015).

****FCC Topic:**** Testing/exposure characterization (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2015

****Exposure:**** 2.45 GHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Effects+of+acute+exposure+to+WIFI+signals+%282>

REF-0048. Effects of Cell Phone Radiofrequency Signal Exposure on Brain Glucose Metabolism. Volkow, N.D., et al. JAMA 305(8):808–813. (2011).

****FCC Topic:**** Scientific evidence relevant to reassessment (Human experimental evidence / neurological effects).

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13

****Dated:**** 2011.

****Exposure:**** Cellular-phone RF exposure for 50 minutes in a randomized crossover study of 47 healthy adults.

****Finding:**** Increased glucose metabolism in brain regions closest to the phone antenna during exposure; the study demonstrates an acute physiological response but does not establish that cell-phone RF exposure causes disease.

****Link:**** <https://jamanetwork.com/journals/jama/fullarticle/645813>

REF-0049. Effects of Exposure to Cellular Phones 950 MHz Electromagnetic Fields on Progesterone, Cortisol and Glucose Levels in Female Hamsters (*Mesocricetus auratus*). Seyednour, R., Chekaniazar, V., et al. (2011). Asian Journal of Animal and Veterinary Advances, 6(11), 1084–1088.

****FCC Topic:**** RF exposure / stress hormones / endocrine and metabolic outcomes.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2011.

****Exposure:**** Female hamsters exposed to 950 MHz electromagnetic fields; the supplied summary reports 200,000 $\mu\text{W}/\text{m}^2$, which should be verified against the article's exposure description.

****Finding:**** Examined whether exposure affected cortisol, progesterone, and glucose levels. Limitation: Hormonal changes in an animal experiment; interpretation depends on exposure duration, dosimetry, controls, and reproducibility.

****Link:****

[https://scholar.google.com/scholar_lookup?journal=Asian%20Journal%20of%20Animal%20and%20Veterinary%20Advances&title=Effects%20of%20exposure%20to%20cellular%20phones%20950%20mhz%20electromagnetic%20fields%20on%20progesterone,%20cortisol%20and%20glucose%20level%20in%20female%20hamsters%20\(Mesocricetus%20auratus\)&author=R%20Seyednour&author=V%20Chekaniazar&volume=6&issue=11&publication_year=2011&pages=1084-1088](https://scholar.google.com/scholar_lookup?journal=Asian%20Journal%20of%20Animal%20and%20Veterinary%20Advances&title=Effects%20of%20exposure%20to%20cellular%20phones%20950%20mhz%20electromagnetic%20fields%20on%20progesterone,%20cortisol%20and%20glucose%20level%20in%20female%20hamsters%20(Mesocricetus%20auratus)&author=R%20Seyednour&author=V%20Chekaniazar&volume=6&issue=11&publication_year=2011&pages=1084-1088)

REF-0050. Effects of long-term pre- and post-natal exposure to 2.45 GHz wireless devices on developing male rat kidney. Kuybulu, A.E., et al. Renal Failure 38(4):571-580. (2016).

****FCC Topic:**** Testing/exposure characterization; Real-world ubiquity/use conditions (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2016

****Exposure:**** 2.45 GHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Effects+of+long-term+pre-+and+post-natal+exposure+to+2>

REF-0051. Effects of microwave at 2.45 GHz radiations on reproductive system of male rats. Kesari, K.K., et al. Toxicological & Environmental Chemistry 92(6):1135-1147. (2010).

FCC Topic: Long-term/biological effects (Reproductive)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2010

Exposure: 2.45 GHz

Link: <https://pubmed.ncbi.nlm.nih.gov/?term=Effects+of+microwave+at+2>

REF-0052. Effects of Prenatal 900 MHz Electromagnetic Field Exposures on the Histology of Rat Kidney. Ulubay, M., et al. International Journal of Radiation Biology 91(1):35-41. (2015).

FCC Topic: Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2017

Exposure: 2.45 GHz

Link: <https://doi.org/10.1016/j.bbr.2017.02.015>

REF-0053. Effects of Prenatal Exposure to a 900 MHz Electromagnetic Field on the Dentate Gyrus of Rats: A Stereological and Histopathological Study. Odaci, E., et al. Brain Research 1238:224–229. (2008).

FCC Topic: Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2017

Exposure: 2.45 GHz

Link: <https://doi.org/10.1016/j.bbr.2017.02.015>

REF-0054. Effects of Prenatal Exposure to WiFi Signal (2.45 GHz) on Postnatal Development and Behavior in Rat: Influence of Maternal Restraint. Othman, H., et al. Behavioral Brain Research 326:291-301. (2017).

FCC Topic: Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2017

Exposure: 2.45 GHz

Link: <https://doi.org/10.1016/j.bbr.2017.02.015>

REF-0055. Effects of Radiofrequency Radiation on Children's Learning and Motor Skills. Chiang, H., et al. (1989). Conference proceedings; linked document hosted by Environmental Health Trust.

FCC Topic: Children's exposure / neurological and developmental outcomes.

HHS Questions: Q12, Q13, Q16.

Dated: 1989.

Exposure: The supplied summary reports 40,000–150,000 $\mu\text{W}/\text{m}^2$

Finding: Cited in discussions of possible associations between RF exposure and children's learning or motor development.

Link: https://ehtrust.org/wp-content/uploads/Proceedings_20_Chiang.pdf

REF-0056. Effects of the Exposure of Mobile Phones on Male Reproduction: A Review of the Literature. La Vignera, S., et al. Journal of Andrology 33(3):350-356. (2012).

FCC Topic: Long-term/biological effects; Testing/exposure characterization (Male fertility)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2012

Exposure: Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Effects+of+the+Exposure+of+Mobile+Phones+on+Male+Reproduction%3A+A+Review+of+the+Literature>

REF-0057. Effects of wi-fi signals on the p300 component of event-related potentials during an auditory hayling task. Papageorgiou, C., et al. Journal of Integrative Neuroscience 10(2):189-202. (2011).

****FCC Topic:**** Long-term/biological effects (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2011

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Effects+of+wi-fi+signals+on+the+p300+component+of+event-related+potentials+during+an+auditory+hayling+task>

REF-0058. Electrohypersensitivity as a Newly Identified and Characterized Neurologic Pathological Disorder: How to Diagnose, Treat, and Prevent It. Belpomme, D., et al. International Journal of Molecular Sciences 21(6):1915. (2020).

****FCC Topic:**** Long-term/biological effects (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2020

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Electrohypersensitivity+as+a+Newly+Identified+and+Characterized+Neurologic+Pathological+Disorder%3A+How+to+Diagnose%2C+Treat%2C+and+Prevent+It>

REF-0059. Electrohypersensitivity: A Functional Impairment Due to an Inaccessible Environment. Johansson, O. Reviews on Environmental Health 30(4):311-321. (2015).

****FCC Topic:**** Scientific evidence relevant to reassessment (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2020

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Electrohypersensitivity+as+a+Newly+Identified+and+Characterized+Neurologic+Pathological+Disorder%3A+How+to+Diagnose%2C+Treat%2C+and+Prevent+It>

REF-0060. Electromagnetic Fields, Pulsed Radiofrequency Radiation, and Epigenetics: How Wireless Technologies May Affect Childhood Development. Sage, C., et al. Child Development 89(1):129-136. (2017).

****FCC Topic:**** Long-term/biological effects; Real-world ubiquity/use conditions (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2017

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Electromagnetic+Fields%2C+Pulsed+Radiofrequency+Radiation%2C+and+Epigenetics%3A+How+Wireless+Technologies+May+Affect+Childhood+Development>

REF-0061. Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. Pall, M.L. Journal of Cellular and Molecular Medicine. 17(8):958-965. (2013).

****FCC Topic:**** Scientific evidence relevant to reassessment (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:** 2017**

****Exposure:** RF; frequency not stated in resource**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Electromagnetic+Fields%2C+Pulsed+Radiofrequency+Radiation%2C+and+Epigenetics%3A+How+Wireless+Technologies+May+Affect+Childhood+Development>

REF-0062. Electromagnetic Fields and Calcium Metabolism in Cardiac Cells. Shuvy, M., et al. (2014). Publication details should be confirmed from the linked record.

****FCC Topic:** Electromagnetic exposure / cardiac cellular function / calcium signaling.**

****HHS Questions:** Q12, Q13, Q16.**

****Dated:** 2014.**

****Exposure:** The supplied summary reports 3,800 $\mu\text{W}/\text{m}^2$ and a possible effect on calcium metabolism in heart cells.**

****Finding:** Cited in relation to experimental research on electromagnetic exposure and cardiac-cell processes.**

****Link:**** <https://www.sciencedirect.com/science/article/abs/pii/S0940299314000657>

REF-0063. Electromagnetic Fields and Immune-System Function. Waliczek, J. (1991). Publication details should be confirmed from the linked document.

****FCC Topic:** Electromagnetic exposure / immune function / biological mechanisms.**

****HHS Questions:** Q12, Q13, Q16.**

****Dated:** 1991.**

****Exposure:** Research concerning electromagnetic fields and immune-system responses. The supplied summary reports 10,000 $\mu\text{W}/\text{m}^2$.**

****Finding:** Discusses possible interactions between electromagnetic fields and immune function. Limitation: Evidence involving ELF fields cannot automatically be generalized to RF.**

****Link:**** <https://escholarship.org/content/qt4r6592x8/qt4r6592x8.pdf>

REF-0064. Electromagnetic Hypersensitivity: Evidence for a Novel Neurological Syndrome. Belpomme, D., Irigaray, P., & colleagues (2018). Publication details should be confirmed from the linked record.

****FCC Topic:** Reported RF/EMF-related symptoms / neurological and symptom surveillance.**

****HHS Questions:** Q10, Q12, Q13, Q16.**

****Dated:** 2018.**

****Exposure:** Individuals reporting symptoms they attribute to electromagnetic-field exposure; the supplied summary emphasizes symptoms at low exposure levels.**

****Finding:** Discusses reported symptoms and proposed clinical or biological features in people describing electromagnetic hypersensitivity (EHS).**

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/28678737/>

REF-0065. Electromagnetic radiation 2450 MHz exposure causes cognition deficit with mitochondrial dysfunction and activation of intrinsic pathway of apoptosis in rats. Gupta, S., et al. Journal of Biosciences 43(2):263-276. (2018).

****FCC Topic:** Long-term/biological effects; Testing/exposure characterization (Neurological/cognitive)**

****HHS Questions:** Q6, Q11, Q12, Q13, Q16**

****Dated:** 2018**

****Exposure:** 2450 MHz**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Electromagnetic+radiation+2450+MHz+exposure+cause+s+cognition+deficit+with+mitochondrial+dysfunction+and+activation+of+intrinsic+pathway+of+a+poptosis+in+rats>

REF-0066. Electromagnetic Radiation at 900 MHz Induces Sperm Apoptosis through bcl-2, bax and caspase-3 Signaling Pathways in Rats. Liu, Q., et al. Journal of Reproductive Health 12:65. (2015).

FCC Topic: Long-term/biological effects (Male fertility)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2018

Exposure: 2450 MHz

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=Electromagnetic+radiation+2450+MHz+exposure+cause+s+cognition+deficit+with+mitochondrial+dysfunction+and+activation+of+intrinsic+pathway+of+a+poptosis+in+rats>

REF-0067. Emotional Behavior Changes and Oxidative Stress Following RF Exposure. Akoev, I. G., et al. (2002). Publication details should be confirmed from the linked record.

FCC Topic: RF exposure / neurological and behavioral outcomes / oxidative stress.

HHS Questions: Q12, Q13, Q16.

Dated: 2002.

Exposure: The supplied summary reports 8,000–10,000 $\mu\text{W}/\text{m}^2$; the exposure conditions and units should be confirmed in the original article.

Finding: Cited in relation to experimental investigations of behavioral and oxidative-stress outcomes after electromagnetic exposure.

Link: <https://europepmc.org/article/med/12125273>

REF-0068. Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations. Khurana, V. G., Hardell, L., Everaert, J., Bortkiewicz, A., Carlberg, M., & Ahonen, M. (2010). International Journal of Occupational and Environmental Health, 16(3), 263–267.

FCC Topic: RF exposure from base stations / neurological symptoms / cancer and epidemiology.

HHS Questions: Q12, Q13, Q15, Q16.

Dated: 2010.

Exposure: Epidemiological research on people living near mobile-phone base stations, with studies using different exposure-assessment methods. The supplied summary reports 500–1,000 $\mu\text{W}/\text{m}^2$, but this is not a universal exposure level for the studies reviewed.

Finding: Reviews epidemiological studies reporting associations between base-station exposure and some health outcomes, including symptoms and cancer-related endpoints.

Link: <https://www.tandfonline.com/doi/abs/10.1179/107735210799160192>

REF-0069. Evaluation of Radiofrequency Exposure Levels from Multiple Wireless Installations in Population Dense Areas in Korea. Kim, B.C., Kim, W.K., Lee, G.T., et al. Bioelectromagnetics 35:603–606. (2014).

FCC Topic: Multiple wireless installations / cumulative environmental exposure.

HHS Questions: Q12, Q15, Q16

Dated: 2014.

Exposure: RF emissions from multiple wireless installations in densely populated areas.

Finding: Evaluated RF exposure associated with multiple wireless installations and is relevant to assessment of environments in which several transmitting sources contribute to measured exposure.

Link: <https://doi.org/10.1002/bem.21874>

REF-0070. Exposure to a 2.5 GHz Non-ionizing Electromagnetic Field Alters Hematological Profiles, Biochemical Parameters, and Induces Oxidative Stress in Male Albino Rats. Bamikole, A.O., et al. Biomedical and Environmental Sciences 32(11):860-863. (2019).

FCC Topic: Testing/exposure characterization (Other health effects)

HHS Questions: Q5, Q7, Q8, Q12, Q13, Q15, Q16

Dated: 2019

****Exposure:**** 2.5 GHz

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/?term=Exposure+to+a+2>

REF-0071. Exposure to Electromagnetic Fields, Cell Phone Use Behaviors, SAR Values, and Changes in Health Following Exposure in Adolescent University Students. Keleş, A. İ., & Uzun Şahin, C. (2021). Archives of Neuropsychiatry, 79(2), 139–148.

****FCC Topic:**** Adolescent exposure / phone-use patterns / self-reported health outcomes.; Adolescent exposure / neurological symptoms / sleep and concentration.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2021.

****Exposure:**** Cellphone-use behaviors and specific absorption rate (SAR) estimates among adolescent university students. The supplied summary reports 100–500 $\mu\text{W}/\text{m}^2$; The study assessed phone-use behaviors and estimated SAR in students.

****Finding:**** Investigated RF exposure estimates, phone-use behaviors, and reported health changes in students.

****Link:**** <https://doi.org/10.1590/0004-282X-ANP-2020-0283>

REF-0072. Exposure to Extremely Low-Frequency Magnetic Fields and the Risk of Childhood Cancer: Update of the Epidemiological Evidence. Schüz, J. Progress in Biophysics and Molecular Biology 107(3):339-342. (2011).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Cancer)

****HHS Questions:**** Q6, Q12, Q16

****Dated:**** 2011

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Exposure+to+Extremely+Low-Frequency+Magnetic+Fields+and+the+Risk+of+Childhood+Cancer%3A+Update+of+the+Epidemiological+Evidence>
REF-0073. Exposure to Magnetic Field Non-Ionizing Radiation and the Risk of Miscarriage: A prospective Cohort Study. Li, D., et al. Scientific Reports 7(17541). (2017).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2017

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Exposure+to+Magnetic+Field+Non-Ionizing+Radiation+and+the+Risk+of+Miscarriage%3A+A+prospective+Cohort+Study>

REF-0074. Exposure to Magnetic fields and the Risk of Poor Sperm Quality. Li, D.K, et al. Journal of Reproductive Toxicology 29(1):86-92. (2010).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2017

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Exposure+to+Magnetic+Field+Non-Ionizing+Radiation+and+the+Risk+of+Miscarriage%3A+A+prospective+Cohort+Study>

REF-0075. Exposure to Magnetic Fields and the Risk of Poor Sperm Quality. Li, D.-K., Yan, B., Li, Z., Gao, E., Miao, M., Gong, D., Weng, X., Ferber, J. R., & Yuan, W. (2010). Reproductive Toxicology, 29(1), 86–92.

****FCC Topic:**** Reproductive health / electromagnetic exposure assessment.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2010.

****Exposure:**** Daily personal measurements of magnetic fields in a population-based case-control study of healthy sperm donors.

****Finding:**** Participants whose 90th-percentile magnetic-field level was at least 1.6 milligauss had approximately twice the odds of abnormal sperm motility and morphology compared with those with lower exposure, after adjustment for confounders.

****Link:**** <https://www.sciencedirect.com/science/article/abs/pii/S0890623809002664>

REF-0076. Exposure to Radio-Frequency Electromagnetic Fields and Behavioral Problems in Bavarian Children and Adolescents. Thomas, S., et al. European Journal of Epidemiology 25(2):135-41. (2009).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2009

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Exposure+to+Radio-Frequency+Electromagnetic+Fields+and+Behavioral+Problems+in+Bavarian+Children+and+Adolescents>

REF-0077. Exposure to Radiofrequency Electromagnetic Fields from Wi-Fi in Australian Schools. (2017).

****FCC Topic:**** Exposure assessment in schools / children.

****HHS Questions:**** Q12, Q13, Q15, Q16

****Dated:**** 2017.

****Exposure:**** Wi-Fi and other RF sources in school environments.

****Finding:**** Measured typical and peak RF levels in 23 Australian schools, including classrooms and schoolyards, providing direct measurements of RF exposure in environments where children spend substantial amounts of time.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Exposure+to+Radiofrequency+Electromagnetic+Fields+from+Wi-Fi+in+Australian+Schools>

REF-0078. Extremely Low frequency Magnetic Fields Induce Spermatogenic Germ Cell Apoptosis: Possible Mechanism. Lee, S., et al. BioMed Research International 2014(567183). (2014).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2014

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Extremely+Low+frequency+Magnetic+Fields+Induce+Spermatogenic+Germ+Cell+Apoptosis%3A+Possible+Mechanism>

REF-0079. Extremely Low Frequency–Electromagnetic Fields Can Decrease Spermatocyte Count and Motility and Change Testicular Tissue. Karbalay-Doust, S., Darabyan, M., Sisakht, M., Haddadi, G., Sotoudeh, N., Haghani, M., & Mortazavi, S. M. J. (2023). Journal of Biomedical Physics and Engineering, 13(2), 135–146.

****FCC Topic:**** Reproductive health / electromagnetic exposure, with an important distinction between ELF and RF.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2023.

****Exposure:**** Extremely low-frequency electromagnetic fields (ELF-EMF), not radiofrequency radiation.

****Finding:**** Reported changes in spermatocyte count, sperm motility, and testicular tissue in an experimental model.

****Link:**** <https://pmc.ncbi.nlm.nih.gov/articles/PMC10111108/>

REF-0080. FCC Consumer Complaints Data. Federal Communications Commission (FCC). (n.d.). Consumer Complaints Data.

****FCC Topic:**** Public complaints / incident reporting / transparency and accountability.

****HHS Questions:**** Q15, Q16; also relevant to Q12 and Q13 where public reporting and exposure-related concerns are addressed.

****Dated:**** Undated public dataset; access; October 10, 2026.

****Exposure:**** Consumer-submitted complaints across FCC-related categories; the dataset is not limited to RF exposure or wireless-infrastructure emissions.

****Finding:**** Provides a publicly accessible record of consumer complaints. The FCC states that complaint information reflects what consumers report and that the agency does not verify the facts alleged. This illustrates the distinction between collecting public complaints and maintaining a standardized technical incident-reporting system with validated measurements, documented investigation, and confirmed corrective action. Limitation: Complaints alone do not establish that an RF exposure event occurred, that exposure limits were exceeded, or that a health effect was caused. The dataset should not be presented as a verified record of RF incidents.

****Link:**** <https://opendata.fcc.gov/Consumer/CGB-Consumer-Complaints-Data/3xyp-aqkj>

REF-0081. Fetal Radiofrequency Radiation Exposure From 800-1900 MHz-Rated Cellular Telephones Affects Neurodevelopment and Behavior in Mice. Aldad, T., et al. Science Reports 2:312. (2012).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2012

****Exposure:**** 1900 MHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Fetal+Radiofrequency+Radiation+Exposure+From+800-1900+MHz-Rated+Cellular+Telephones+Affects+Neurodevelopment+and+Behavior+in+Mice>

REF-0082. From the Cover: 2.45-GHz Microwave Radiation Impairs Hippocampal Learning and Spatial Memory: Involvement of Local Stress Mechanism-Induced Suppression of iGluR/ERK/CREB Signaling. Shahin, S., et al. Toxicological Sciences 161(2):349-374. (2018).

****FCC Topic:**** Long-term/biological effects (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** Not stated in resource

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/?term=From+the+Cover%3A+2>

REF-0083. Genetics, DNA, and cellular effects

REF-0084. Genotoxicity Induced by Foetal and Infant Exposure to Magnetic Fields and Modulation of Ionising Radiation Effects. Udrouiu, I., et al. PLoS One10(11):E0142259. (2015).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Genotoxicity+Induced+by+Foetal+and+Infant+Exposure+to+Magnetic+Fields+and+Modulation+of+Ionising+Radiation+Effects>

REF-0085. GSM Base Station Electromagnetic Radiation and Oxidative Stress in Rats. Yurekli, A. I., Ozkan, M., Kalkan, T., Saybasili, H., Tuncel, H., Atukeren, P., Gumustas, K., & Seker, S. (2006). Electromagnetic Biology and Medicine, 25(3), 177–188.

****FCC Topic:**** RF exposure / oxidative stress / laboratory evidence.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 2006.

****Exposure:**** Rats exposed to 945 MHz GSM base-station-frequency radiation in a controlled GTEM-cell environment. The supplied summary reports 280,000 $\mu\text{W}/\text{m}^2$; confirm the original paper's exposure metric before using this value.

****Finding:**** Investigated oxidative-stress markers in rats exposed to GSM-frequency radiation.

****Link:**** <https://www.tandfonline.com/doi/full/10.1080/15368370600875042>

REF-0086. Guidance for Assessment, Evaluation and Monitoring of Human Exposure to Radio Frequency Electromagnetic Fields. ITU-T K.91. International Telecommunication Union. (2024).

****FCC Topic:**** RF exposure assessment / multiple-source exposure.

****HHS Questions:**** Q9, Q12, Q15, Q16

****Dated:**** 2024.

****Exposure:**** RF electromagnetic fields from multiple sources.

****Finding:**** Provides guidance for assessing, evaluating, and monitoring RF exposure and addresses simultaneous exposure to multiple sources, including cumulative calculations in which contributions from different frequencies are considered together.

****Link:**** <https://www.itu.int/rec/T-REC-K.91>

REF-0087. Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz). International Commission on Non-Ionizing Radiation Protection (ICNIRP). Health Physics 118(5):483–524. (2020).

****FCC Topic:**** Exposure assessment and exposure limits.

****HHS Questions:**** Q9, Q10, Q12, Q13, Q15, Q16

****Dated:**** 2020.

****Exposure:**** 100 kHz–300 GHz.

****Finding:**** Provides the principal international framework for assessing RF exposure, including frequency, antenna characteristics, field strength, exposure geometry, averaging, and multiple-source exposure.

****Link:**** <https://www.icnirp.org/en/publications/article/rf-guidelines-2020.html>

REF-0088. Habits of Cell Phone usage and Sperm Quality - Does It Warrant Attention? Zilberlicht, A., et al. Reproductive BioMedicine Online 31(3):421-426. (2015).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Habits+of+Cell+Phone+usage+and+Sperm+Quality+-+Does+It+Warrant+Attention%3F+Zilberlicht%2C+A>

REF-0089. Hepatic injury induced by radio frequency waves emitted from conventional Wi-Fi devices in Wistar rats. Fahmy, H.M., et al. Human & Experimental Toxicology 40(1):136-147. (2021).

****FCC Topic:**** Scientific evidence relevant to reassessment (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2021

****Exposure:**** Wi-Fi; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Hepatic+injury+induced+by+radio+frequency+waves+emitted+from+conventional+Wi-Fi+devices+in+Wistar+rats>

REF-0090. Histopathologic effects of mobile phone radiation exposure on the testes and sperm parameters: A systemic literature review of animal studies. Assefa EM, Abdu SM, Frontiers in Reproductive Health, Vol 6 (2025)

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:** 2025**

****Exposure:** Mobile/cellular RF; frequency not stated in resource**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Assefa+EM%2C+Abdu+SM%2C+Histopathologic+effect+s+of+mobile+phone+radiation+exposure+on+the+tetes+and+sperm+parameters%3A+A+syste mic+literature+review+of+animal+studies%2C+Frontiers+in+Reproductive+Health%2C+Vol+6+%282025%29>

REF-0091. Human Exposure Assessment to Wearable Antennas: Effect of Position and Interindividual Anatomical Variability. Lemaire, D., et al. International Journal of Environmental Research and Public Health 19(10):6206. (2022).

****FCC Topic:** Wearable-device exposure / anatomical variability.**

****HHS Questions:** Q9, Q12, Q13, Q15, Q16**

****Dated:** 2022.**

****Exposure:** 2.45 GHz wearable antenna.**

****Finding:** Modeled six realistic antenna configurations on male and female anatomical models. Exposure varied according to antenna position, with the highest calculated exposure concentrated in tissue immediately beneath the antenna.**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Human+Exposure+Assessment+to+Wearable+Antenna s+Effect+of+Position+and+Interindividual+Anatomical+Variability>

REF-0092. Human Exposure to EMF from 5G Base Stations: Analysis, Evaluation and Comparison of Different Assessment Methods. Expósito, N., et al. (2024).

****FCC Topic:** 5G infrastructure / exposure measurement methodology.**

****HHS Questions:** Q12, Q15, Q16**

****Dated:** 2024.**

****Exposure:** RF fields from 5G base stations.**

****Finding:** Compared broadband field probes, spectrum analyzers, and drive-test scanners and demonstrated that the selected measurement method can affect characterization of exposure.**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Human+Exposure+to+EMF+from+5G+Base+Stations+A nalysis+Evaluation+and+Comparison>

REF-0093. Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices. Atasoy, H.I., et al. Journal of Pediatric Urology 9(2):223-239. (2013).

****FCC Topic:** Long-term/biological effects (Reproductive)**

****HHS Questions:** Q11, Q12, Q13, Q16**

****Dated:** 2013**

****Exposure:** Wi-Fi; frequency not stated in resource**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Immunohistopathologic+demonstration+of+deleterious+ effects+on+growing+rat+testes+of+radiofrequency+waves+emitted+from+conventional+Wi-Fi+d evices>

REF-0094. Impact of 900 MHz Electromagnetic Field Exposure on Main Male Reproductive Hormone Levels: A Rattus norvegicus Model. Sepehrimanesh, M., Saeb, M., Nazifi, S., Kazemipour, N., Jelodar, G., & Saeb, S. (2014). International Journal of Biometeorology, 58(7), 1657–1663.

****FCC Topic:** RF exposure / male reproductive hormones / animal evidence.**

****HHS Questions:** Q12, Q13, Q16.**

****Dated:** 2014.**

****Exposure:**** Twenty male rats exposed to 900 MHz RF for 1, 2, or 4 hours per day over 30 days, with a sham-exposed comparison group. The supplied summary reports 1,000,000 $\mu\text{W}/\text{m}^2$.

****Finding:**** Evaluated changes in testosterone and other reproductive hormones after repeated exposure.

****Link:**** <https://link.springer.com/article/10.1007/s00484-013-0771-7>

REF-0095. In Vitro Effect of Cell Phone Radiation on Motility, DNA Fragmentation and Clusterin Gene Expression in Human Sperm. Zalata, A., et al. International Journal of Fertility and Sterility 9(1):129-136. (2015).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=In+Vitro+Effect+of+Cell+Phone+Radiation+on+Motility%2C+DNA+Fragmentation+and+Clusterin+Gene+Expression+in+Human+Sperm>

REF-0096. In-Situ Measurements of Radiofrequency Electromagnetic Fields Around 5G Macro Base Stations in the UK. Calderon, A., Addison, D. & Peyman, A. Bioelectromagnetics 46(5). (2025).

****FCC Topic:**** Current wireless infrastructure exposure measurements / 5G.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** 2025.

****Exposure:**** RF fields surrounding active 5G macro base stations.

****Finding:**** Measurements were performed at 56 active 5G macro base stations across 30 publicly accessible locations, evaluating background conditions and different network-activity scenarios. The study provides current field measurements around real-world wireless infrastructure.

****Link:**** <https://doi.org/10.1002/bem.70012>

REF-0097. Indicative SAR Levels Due to an Active Mobile Phone in a Front Trouser Pocket in Proximity to Common Metallic Objects. Whittow, WG., et al. IEEE Xplore 149-152 (2008).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2008

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Indicative+SAR+Levels+Due+to+an+Active+Mobile+Phone+in+a+Front+Trouser+Pocket+in+Proximity+to+Common+Metallic+Objects>

REF-0098. Influence of Pregnancy Stage and Fetus Position on the Whole-Body and Local Exposure of the Fetus to RF-EMF. Varsier, N. et al. Physics in Medicine and Biology 59(17):4913-26. (2014).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16, Q5, Q7, Q8

****Dated:**** 2014

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Influence+of+Pregnancy+Stage+and+Fetus+Position+on+the+Whole-Body+and+Local+Exposure+of+the+Fetus+to+RF-EMF>

REF-0099. Laboratory studies: oxidative stress, hormones, calcium signaling, and the blood-brain barrier

REF-0100. Lai H. Genetic effects of non-ionizing electromagnetic fields. Electromagnetic Biology Med. Apr 3;40(2):264-273. (2021)

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2021

****Exposure:**** EMF; frequency not stated in resource

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/?term=Lai+H>

REF-0101. Lasting Hepatotoxic Effects of Prenatal Mobile Phone Exposure. Yilmaz, A., et al. The Journal of Maternal-Fetal & Neonatal Medicine 30(11):1355-1359 (2017).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2017

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Lasting+Hepatotoxic+Effects+of+Prenatal+Mobile+Phone+Exposure>

REF-0102. Long-term exposure of 2450 MHz electromagnetic radiation induces stress and anxiety like behavior in rats. Gupta, S.K., et al. Neurochemistry International 128:1-13. (2019).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2019

****Exposure:**** 2450 MHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Long-term+exposure+of+2450%E2%80%AFMHz+electromagnetic+radiation+induces+stress+and+anxiety+like+behavior+in+rats>

REF-0103. Long-Term Exposure to 4G Smartphone Radiofrequency Electromagnetic Radiation Diminished Male Reproductive Potential by Directly Disrupting Spck3-MMP2-BTB Axis in the Testes of Adult Rats. Yu, G., et al. Science of The Total Environment 698(133860). (2020).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2020

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Long-Term+Exposure+to+4G+Smartphone+Radiofrequency+Electromagnetic+Radiation+Diminished+Male+Reproductive+Potential+by+Directly+Disrupting+Spck3-MMP2-BTB+Axis+in+the+Testes+of+Adult+Rats>

REF-0104. Long-term exposure to electromagnetic radiation from mobile phones and Wi-Fi devices decreases plasma prolactin, progesterone, and estrogen levels but increases uterine oxidative stress in pregnant rats and their offspring. Yüksel, M., et al. Endocrine 52(2):352-362. (2016).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Reproductive)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2020

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Long-Term+Exposure+to+4G+Smartphone+Radiofrequency+Electromagnetic+Radiation+Diminished+Male+Reproductive+Potential+by+Directly+Disrupting+Spck3-MMP2-BTB+Axis+in+the+Testes+of+Adult+Rats>

REF-0105. Longitudinal Study of Exposure to Radio Frequencies at Population Scale. Boussad, Y., et al. Environment International 162:107144. (2022).

****FCC Topic:**** Real-world cumulative and multiple-source RF exposure.

****HHS Questions:**** Q12, Q13, Q15, Q16

****Dated:**** 2022.

****Exposure:**** Cellular antennas, Wi-Fi access points, and Bluetooth devices.

****Finding:**** Analyzed crowd-sourced RF measurements from 254,410 unique users in 13 countries from 2017–2020 and examined changes in exposure over time and contributions from multiple RF sources.

****Link:**** <https://doi.org/10.1016/j.envint.2022.107144>

REF-0106. Lost Opportunities for Cancer Prevention: Historical Evidence on Early Warnings with Emphasis on Radiofrequency Radiation. Hardell, L., et al. Reviews on Environmental Health 000010151520200168. (2021).

****FCC Topic:**** Long-term/biological effects (Cancer)

****HHS Questions:**** Q6, Q12, Q16

****Dated:**** 2021

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Lost+Opportunities+for+Cancer+Prevention%3A+Historical+Evidence+on+Early+Warnings+with+Emphasis+on+Radiofrequency+Radiation>

REF-0107. Low intensity microwave radiation induced oxidative stress, inflammatory response and DNA damage in rat brain. Megha, K. et al. NeuroToxicology 51:158-165. (2015).

****FCC Topic:**** Long-term/biological effects (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Low+intensity+microwave+radiation+induced+oxidative+stress%2C+inflammatory+response+and+DNA+damage+in+rat+brain>

REF-0108. Male Fertility and its Association with Occupational and Mobile Phone Tower Hazards: An Analytical Study. Al-Quzwini, O., et al. Middle East Fertility Society Journal 21(4):236-240. (2016).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2016

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Male+Fertility+and+its+Association+with+Occupational+and+Mobile+Phone+Tower+Hazards%3A+An+Analytical+Study>

REF-0109. Maternal Exposure to a Continuous 900-MHz Electromagnetic Field Provokes Neuronal Loss and Pathological Changes in Cerebellum of 32-Day-Old Female Rat Offspring. Odacı, E., et al. Journal of Chemical Neuroanatomy 75(Pt B):105-110. (2015).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Maternal+Exposure+to+a+Continuous+900-MHz+Electromagnetic+Field+Provokes+Neuronal+Loss+and+Pathological+Changes+in+Cerebellum+of+32-Day-Old+Female+Rat+Offspring>

REF-0110. Maternal Occupational Exposure to Extremely Low Frequency Magnetic Fields and the Risk of Brain Cancer in the Offspring. Li, P, et al. Cancer Causes & Control 20(6):945-55. (2009).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2009

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Maternal+Occupational+Exposure+to+Extremely+Low+Frequency+Magnetic+Fields+and+the+Risk+of+Brain+Cancer+in+the+Offspring>
REF-0111. Measurements of Radiofrequency Radiation with a Body-Borne Exposimeter in Swedish Schools with Wi-Fi. Hedendahl, L.K., et al. *Frontiers in Public Health* 5(279):1-14. (2017).

****FCC Topic:**** Real-world ubiquity/use conditions (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2017

****Exposure:**** Wi-Fi; frequency not stated in resource

****Link:**** <https://doi.org/10.3389/fpubh.2017.00279>

REF-0112. Mobile Phone Radiation Induces Reactive Oxygen Species Production and DNA Damage in Human Spermatozoa In Vitro. De Luliis, G., et al. *PLoS ONE* 4(7). (2009).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2009

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Mobile+Phone+Radiation+Induces+Reactive+Oxygen+Species+Production+and+DNA+Damage+in+Human+Spermatozoa+In+Vitro>
REF-0113. Mobile Phone Use During Pregnancy: Which Association With Fetal Growth? Boileau, N., et al. *Journal of Gynecology Obstetrics and Human Reproduction* 49(8):101852. (2020).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2020

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Mobile+Phone+Use+During+Pregnancy%3A+Which+As+sociation+With+Fetal+Growth%3F+Boileau%2C+N>

REF-0114. Modulatory Effect of 900 MHz Radiation on Biochemical and Reproductive Parameters in Rats. Narayanan, SN., et al. *Bratislava Medical Journal* 119(9):581-587. (2018).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** 900 MHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Modulatory+Effect+of+900+MHz+Radiation+on+Bioche+mical+and+Reproductive+Parameters+in+Rats>

REF-0115. Mother's Exposure to Electromagnetic Fields Before and During Pregnancy is Associated with Risk of Speech Problems in Offspring. Zarei, S., et al. *Journal of Biomedical Physics and Engineering* 9(1):61-68. (2019).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2019

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Mother%E2%80%99s+Exposure+to+Electromagnetic+F>

ields+Before+and+During+Pregnancy+is+Associated+with+Risk+of+Speech+Problems+in+Offspring

REF-0116. Multiple Assessment Methods of Prenatal Exposure to Radio Frequency Radiation from Telecommunication in the Mothers and Children's Environmental Health (MOCEH) Study. Choi, KH., et al. International Journal of Occupational Medicine and Environmental Health 29(6):959-972 (2016).

FCC Topic: Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2016

Exposure: Not stated in resource

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=Multiple+Assessment+Methods+of+Prenatal+Exposure+to+Radio+Frequency+Radiation+from+Telecommunication+in+the+Mothers+and+Children%E2%80%99s+Environmental+Health+%28MOCEH%29+Study>

REF-0117. National Toxicology Program Technical Report TR-595 — Toxicology and Carcinogenesis Studies in Sprague Dawley Rats Exposed to Whole-Body Radio Frequency Radiation at a Frequency (900 MHz) and Modulations (GSM and CDMA) Used by Cell Phones. National Toxicology Program. NTP TR-595. (2018).

FCC Topic: Scientific evidence relevant to reassessment (Cancer / long-term exposure).

HHS Questions: Q5, Q7, Q8, Q12, Q13, Q16

Dated: 2018.

Exposure: 900 MHz GSM/CDMA whole-body RF exposure at 0, 1.5, 3, and 6 W/kg.

Finding: The NTP reported clear evidence of carcinogenic activity in exposed male rats based principally on malignant heart schwannomas, with additional findings involving brain gliomas and adrenal tumors.

Link: <https://ntp.niehs.nih.gov/publications/reports/tr/tr595>

REF-0118. National Toxicology Technical Report on Cell Phones and Cancer. Toxicology and Carcinogenesis Studies in Sprague Dawley (Hsd:Sprague Dawley SD) Rats Exposed to Whole-body Radio Frequency Radiation at a Frequency (900 Mhz) and Modulations (GSM and CDMA) Used by Cell Phones. National Toxicology Program TR595:1-466. (2018).

FCC Topic: Long-term/biological effects (Cancer); Scientific evidence relevant to reassessment (Other health effects)

HHS Questions: Q5, Q7, Q8, Q12, Q13, Q15, Q16

Dated: 2018

Exposure: 900 Mhz

Link: <https://pubmed.ncbi.nlm.nih.gov/33562898/>

REF-0119. Neurodegenerative Changes and Apoptosis Induced by Intrauterine and Extrauterine Exposure of Radiofrequency Radiation. Güler, G., et al. Journal of Chemical Neuroanatomy 75(Pt B):128-133. (2015).

FCC Topic: Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2015

Exposure: RF; frequency not stated in resource

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=Neurodegenerative+Changes+and+Apoptosis+Induced+by+Intrauterine+and+Extrauterine+Exposure+of+Radiofrequency+Radiation>

REF-0120. Numerical evaluation of human exposure to WiMax patch antenna in tablet or laptop. Siervo, B., et al. Bio Electro Magnetism 39(5):414-422. (2018).

FCC Topic: Testing/exposure characterization (Other health effects)

HHS Questions: Q5, Q7, Q8, Q12, Q13, Q15, Q16, Q11

****Dated:** 2018**

****Exposure:** Not stated in resource**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Numerical+evaluation+of+human+exposure+to+WiMax+patch+antenna+in+tablet+or+laptop>

REF-0121. Oxidative Stress of Brain and Liver is Increased by Wi-Fi (2.45 GHz) Exposure of Rats During Pregnancy and the Development of Newborns. Çelik, Ö., et al. Journal of Chemical Neuroanatomy 75(Pt B):134-139. (2015).

****FCC Topic:** Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)**

****HHS Questions:** Q11, Q12, Q13, Q16**

****Dated:** 2016**

****Exposure:** 2.45GHz**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Oxidative+stress+of+brain+and+liver+is+increased+by+Wi-Fi+%282>

REF-0122. Oxidative stress of brain and liver is increased by Wi-Fi (2.45GHz) exposure of rats during pregnancy and the development of newborns. Çelik, Ö., et al. Journal of Chemical Neuroanatomy 75(Part B):134-139. (2016).

****FCC Topic:** Long-term/biological effects; Testing/exposure characterization (Neurological/cognitive/other health effects)**

****HHS Questions:** Q5, Q6, Q7, Q11, Q12, Q13, Q15, Q16**

****Dated:** 2016**

****Exposure:** 2.45GHz**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Oxidative+stress+of+brain+and+liver+is+increased+by+Wi-Fi+%282>

REF-0123. Permeability of the Blood–Brain Barrier Induced by 915 MHz Electromagnetic Radiation, Continuous Wave and Modulated at 8, 16, 50, and 200 Hz. Salford, L. G., Brun, A., Stureson, K., Eberhardt, J. L., & Persson, B. R. (1994). Microscopy Research and Technique, 27(6), 535–542.

****FCC Topic:** RF exposure / neurological mechanisms / blood–brain barrier.**

****HHS Questions:** Q12, Q13, Q16.**

****Dated:** 1994.**

****Exposure:** Rats exposed to 915 MHz RF under continuous-wave and several amplitude-modulation conditions. The supplied summary reports 1,200,000 $\mu\text{W}/\text{m}^2$.**

****Finding:** Investigated whether RF exposure altered blood–brain barrier permeability in an animal model.**

****Link:** <https://pubmed.ncbi.nlm.nih.gov/8012056/>**

REF-0124. Personal Exposure to Radio-Frequency Electromagnetic Fields in Europe: Is There a Generation Gap? Birks, L.E., et al. Environment International 121:894–902. (2018).

****FCC Topic:** Children's exposure / parent-child exposure comparison.**

****HHS Questions:** Q12, Q13, Q15, Q16**

****Dated:** 2018.**

****Exposure:** Environmental downlink, mobile-phone uplink, broadcast, DECT, and Wi-Fi sources.**

****Finding:** Simultaneous 24–72-hour personal measurements were obtained from 294 parent-child pairs in five European countries and evaluated differences in exposure associated with activities and behavior.**

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Personal+exposure+to+radio-frequency+electromagnetic+fields+in+Europe+Is+there+a+generation+gap>

REF-0125. Personal Exposure to Radiofrequency Electromagnetic Fields in Adolescents — 5G-Era Measurements. Swiss adolescent 5G-era study. (2026).

****FCC Topic:**** Children's exposure / evolving wireless technology.

****HHS Questions:**** Q12, Q13, Q15, Q16

****Dated:**** 2026.

****Exposure:**** Multiple RF bands including Wi-Fi, Bluetooth, cellular uplink/downlink, broadcast, and 5G TDD.

****Finding:**** Provides current real-world personal exposure measurements after the introduction of 5G and demonstrates that exposure consists of contributions from multiple technologies rather than a single source.

****Link:**** <https://doi.org/10.1016/j.envres.2026.124775>

REF-0126. Personal Radiofrequency Electromagnetic Field Exposure Among Swiss Adolescents in the 5G Era. Roser, K., et al. Environment Research 304:124775. (2026).

****FCC Topic:**** Children's/adolescent exposure / 5G-era exposure.

****HHS Questions:**** Q12, Q13, Q15, Q16

****Dated:**** 2026.

****Exposure:**** Thirty-five RF frequency bands measured for approximately 72 hours in 143 adolescents.

****Finding:**** Wi-Fi/Bluetooth accounted for approximately 35% of categorized exposure, broadcast 31%, uplink 19%, downlink 10%, and 5G TDD 4%; the study provides current evidence on the composition of personal RF exposure in the 5G era.

****Link:**** <https://doi.org/10.1016/j.envres.2026.124775>

REF-0127. Personal Radiofrequency Electromagnetic Field Exposure Measurements in Swiss Adolescents. Roser, K., Schoeni, A., Struchen, B., et al. Environment International 99:303–314. (2017).

****FCC Topic:**** Children's/adolescent exposure / personal exposure assessment.

****HHS Questions:**** Q12, Q13, Q15, Q16

****Dated:**** 2017.

****Exposure:**** 13 RF frequency bands measured with personal exposimeters for three days in 90 adolescents aged 13–17.

****Finding:**** Mobile phones were the largest contributor to measured personal exposure, while environmental sources including base stations, WLAN access points, and other phones also contributed.

****Link:**** <https://doi.org/10.1016/j.envint.2016.12.008>

REF-0128. Personal Radiofrequency Electromagnetic Field Exposure of Adolescents in the Greater London Area in the SCAMP Cohort and the Association with Restrictions on Permitted Use of Mobile Communication Technologies at School and at Home. Calvente, I., et al. Environment International 212:113252. (2022).

****FCC Topic:**** Children's/adolescent exposure / multiple RF sources.

****HHS Questions:**** Q12, Q13, Q15, Q16

****Dated:**** 2022.

****Exposure:**** Sixteen RF frequency bands including mobile-phone uplink/downlink, Wi-Fi, DECT, and broadcast sources.

****Finding:**** Personal RF exposure was measured in 148 adolescents for a median of 47 hours, providing real-world information on the combination of personal-device and environmental RF exposure.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Personal+radiofrequency+electromagnetic+field+exposure+of+adolescents+in+the+Greater+London+area+SCAMP>

REF-0129. Postnatal Development and Behavior Effects of In-Utero Exposure of Rats to Radiofrequency Waves Emitted From Conventional WiFi Devices. Othman, H., et al. Environmental Toxicology and Pharmacology 52:239-247 (2017).

FCC Topic: Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2017

Exposure: Wi-Fi; frequency not stated in resource

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=Postnatal+Development+and+Behavior+Effects+of+In-Utero+Exposure+of+Rats+to+Radiofrequency+Waves+Emitted+From+Conventional+WiFi+Devices>

REF-0130. Prenatal and Postnatal Exposure to Cell Phone Use and Behavioral Problems in Children. Divan, HA., et al. Epidemiology 19(4):523-29 (2008).

FCC Topic: Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2008

Exposure: Mobile/cellular RF; frequency not stated in resource

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=Prenatal+and+Postnatal+Exposure+to+Cell+Phone+Use+and+Behavioral+Problems+in+Children>

REF-0131. Prenatal Exposure to Extremely Low Frequency Magnetic Field and Its Impact on Fetal Growth. Ren, Y., et al. Environmental Health 18(1):6. (2019).

FCC Topic: Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2019

Exposure: Not stated in resource

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=Prenatal+Exposure+to+Extremely+Low+Frequency+Magnetic+Field+and+Its+Impact+on+Fetal+Growth>

REF-0132. Prolonged RF Exposure, Sleep, Mood, and Neurological Symptoms. Belyaev, I., et al. (2016). Publication details should be confirmed from the linked article.

FCC Topic: RF exposure / sleep / mood and neurological outcomes.

HHS Questions: Q12, Q13, Q16.

Dated: 2016.

Exposure: The supplied summary describes prolonged RF exposure and reports sleep disturbances, mood changes, and mild neurological effects.

Finding: Cited in discussions of possible neurological and sleep-related effects associated with RF exposure. Limitation: The exact article title, study design, exposure conditions, and findings should be verified before attributing a particular effect to the source.

Link: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5383603/>

REF-0133. Prospective Cohort Analysis of Cellphone Use and Emotional and Behavioural Difficulties in Children. Sudan, M., et al. Journal of Epidemiology and Community Health 70(12):1207-1213. (2016).

FCC Topic: Long-term/biological effects; Children/developmental exposure (Neurological/cognitive)

HHS Questions: Q6, Q11, Q12, Q13, Q16

Dated: 2016

Exposure: Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Prospective+Cohort+Analysis+of+Cellphone+Use+and+Emotional+and+Behavioural+Difficulties+in+Children>

REF-0134. Pyramidal Cell Loss in the Cornu Ammonis of 32-day-old Female Rats Following Exposure to a 900 Megahertz Electromagnetic Field During Prenatal Days 13–21. Bas, O., et al. *NeuroQuantology* 11(4):591-599. (2013).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2013

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Pyramidal+Cell+Loss+in+the+Cornu+Ammonis+of+32-day-old+Female+Rats+Following+Exposure+to+a+900+Megahertz+Electromagnetic+Field+During+Prenatal+Days+13%E2%80%9321>

REF-0135. Radiations and Male Fertility. Kesari, K., et al. *Reproductive Biology and Endocrinology* 16(118). (2018).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** Not stated in resource

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/?term=Radiations+and+Male+Fertility>

REF-0136. Radio Frequency Electromagnetic Radiation (Rf-EMR) from GSM Mobile Phones Induces Oxidative Stress and Reduces Sperm Motility in Rats. Mailankot, M., et al. *Clinics (San Paulo)* 64(6):561-5. (2009).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2009

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Radio+Frequency+Electromagnetic+Radiation+%28Rf-EMR%29+from+GSM+Mobile+Phones+Induces+Oxidative+Stress+and+Reduces+Sperm+Motility+in+Rats>

REF-0137. Radiofrequency Exposure from Wireless LANs Utilizing Wi-Fi Technology. Foster, K.R. (2007).

****FCC Topic:**** Wi-Fi exposure assessment.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** 2007.

****Exposure:**** Wi-Fi RF fields.

****Finding:**** Measurements were conducted at 356 locations at 55 sites in the United States and several European countries, including residences, commercial spaces, healthcare facilities, educational institutions, and public spaces.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Radiofrequency+Exposure+from+Wireless+LANs+Utilizing+Wi-Fi+Technology>

REF-0138. Radiofrequency Exposure of People Living Near Mobile-Phone Base Stations in France. Breckenkamp, J., et al. *Environment International*. (2021).

****FCC Topic:**** Exposure assessment / base-station infrastructure.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** 2021.

****Exposure:**** Multiple RF sources including cellular, Wi-Fi, and broadcast signals.

****Finding:**** Combined spot measurements in 354 homes with 48-hour and 7-day personal measurements; examined window orientation, line of sight, distance, and apartment floor as factors affecting exposure.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Radiofrequency+exposure+of+people+living+near+mobile-phone+base+stations+in+France>

REF-0139. Radiofrequency Radiation (900 MHz)-Induced DNA Damage and Cell Cycle Arrest in Testicular Germ Cells in Swiss Albino Mice. Pandey, N., et al. Toxicology and Industrial Health 33(4) 373-384. (2017).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2017

****Exposure:**** 900 MHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Radiofrequency+Radiation+%28900+MHz%29-Induced+DNA+Damage+and+Cell+Cycle+Arrest+in+Testicular+Germ+Cells+in+Swiss+Albino+Mice>

REF-0140. Radiofrequency Radiation and Calcium Signaling in Intestinal Epithelial Cells.

Somozy, P. (1993). Microscopy.

****FCC Topic:**** RF exposure / cellular signaling / laboratory mechanisms.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 1993.

****Exposure:**** The supplied summary reports 5,000,000 $\mu\text{W}/\text{m}^2$ and changes in intercellular calcium in intestinal epithelial cells.

****Finding:**** Cited in discussions of possible RF-related changes in cellular calcium signaling.

****Link:**** <https://digitalcommons.usu.edu/microscopy/vol7/iss4/15/>

REF-0141. Radiofrequency Radiation-Induced Calcium Ion Efflux Enhancement from Human and Other Neuroblastoma Cells in Culture. Dutta, S. K., Ghosh, B., & Blackman, C. F. (1989). Bioelectromagnetics, 10(2), 197–202.

****FCC Topic:**** RF exposure / cellular calcium signaling / biological mechanisms.

****HHS Questions:**** Q12, Q13, Q16.

****Dated:**** 1989.

****Exposure:**** Cultured neuroblastoma cells exposed to 147 MHz amplitude-modulated RF at specified specific absorption rates (SARs) from 0.0005 to 0.1 W/kg. The paper reports effects at particular SAR values; the supplied 125,000 $\mu\text{W}/\text{m}^2$.

****Finding:**** Reported enhanced calcium-ion efflux under some exposure and modulation conditions.

****Link:**** <https://onlinelibrary.wiley.com/doi/abs/10.1002/bem.2250100208>

REF-0142. RAPD Profiling, DNA Fragmentation, and Histomorphometric Examination in Brains of Wistar Rats Exposed to Indoor 2.5 Ghz Wi-Fi Devices Radiation. Ibitayo, A.O., et al. BioMed Research International 2017(8653286):1-6. (2017).

****FCC Topic:**** Scientific evidence relevant to reassessment (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2017

****Exposure:**** 2.5 Ghz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=RAPD+Profiling%2C+DNA+Fragmentation%2C+and+Histomorphometric+Examination+in+Brains+of+Wistar+Rats+Exposed+to+Indoor+2>

REF-0143. Recommendation ITU-T K.91 — Guidance for Assessment, Evaluation and Monitoring of Human Exposure to Radio Frequency Electromagnetic Fields. International Telecommunication Union (ITU-T). (2024). Recommendation ITU-T K.91 (01/2024).

****FCC Topic:**** RF exposure assessment / fixed wireless infrastructure / monitoring and compliance.

****HHS Questions:**** Q15, Q16; also relevant to Q12 and Q13 where exposure assessment and monitoring are discussed.

****Dated:**** 2024.

****Exposure:**** Human exposure to RF electromagnetic fields from telecommunications installations and multiple RF sources in real-world environments.

****Finding:**** Provides technical guidance for assessing, evaluating, and monitoring human RF exposure, including around telecommunications installations such as base stations. Its coverage of environments with multiple RF sources supports the technical feasibility of structured, comparable exposure assessments. Limitation: This is a technical recommendation and assessment framework; it does not, by itself, establish a legal requirement for continuous monitoring, automatic alerts, mandatory incident reporting, or public notification.

****Link:**** <https://www.itu.int/rec/T-REC-K.91/en>

REF-0144. Report of Final Results Regarding Brain and Heart Tumors in Sprague-Dawley Rats Exposed From Prenatal Life Until Natural Death to Mobile Phone Radiofrequency Field Representative of a 1.8 GHz GSM Base Station Environmental Emission. Falcioni, L, et al. Environmental Research 165:496-503. (2018).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure (Cancer/Other health effects)

****HHS Questions:**** Q5, Q6, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2018

****Exposure:**** 1.8 GHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Report+of+Final+Results+Regarding+Brain+and+Heart+Tumors+in+Sprague-Dawley+Rats+Exposed+From+Prenatal+Life+Until+Natural+Death+to+Mobile+Phone+Radiofrequency+Field+Representative+of+a+1>

REF-0145. Reproductive and Developmental Effects of EMF in Vertebrate Animal Models. Pourlis, A.F. Pathophysiology 16(2-3):179-89. (2009).

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2009

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Reproductive+and+Developmental+Effects+of+EMF+in+Vertebrate+Animal+Models>

REF-0146. Residential Exposure to Radiofrequency Fields from Mobile Phone Base Stations and Broadcast Transmitters: A Population-Based Survey with Personal Meter. Neubauer, G., et al. Occupational and Environmental Medicine 66(8):550–556. (2009).

****FCC Topic:**** Exposure assessment / base-station exposure.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** 2009.

****Exposure:**** RF fields from mobile-phone base stations and broadcast transmitters; 24-hour personal measurements in 200 people.

****Finding:**** Measured personal exposure did not simply decline with distance from transmitting infrastructure; for some frequency bands, exposure was highest at locations hundreds of meters from the transmitter.

****Link:**** <https://doi.org/10.1136/oem.2008.044180>

REF-0147. Resolution of Notice of Inquiry, Reassessment of FCC Radiofrequency Exposure Limits and Policies. Federal Communications Commission (FCC). (2019). FCC 19-126.

****FCC Topic:**** RF exposure limits and policies / compliance framework / regulatory oversight.

****HHS Questions:**** Q15, Q16; also relevant to Q12 and Q13.

****Dated:**** 2019.

****Exposure:**** RF emissions from FCC-regulated radiofrequency devices and facilities, in the context of the FCC's RF exposure rules and evaluation policies.

****Finding:**** Documents the FCC's regulatory review and decisions concerning its RF exposure framework, providing background for understanding the existing compliance and evaluation approach. It can be cited as regulatory context when proposing supplemental operational monitoring and incident escalation.

****Link:**** https://docs.fcc.gov/public/attachments/FCC-19-126A1_Rcd.pdf

REF-0148. Review of Published Literature between 2008 and 2018 of Relevance to Radiofrequency Radiation and Cancer. U.S. Food and Drug Administration (FDA), Center for Devices and Radiological Health. (2020; analysis subsequently updated through August 2019).

****FCC Topic:**** RF exposure and cancer / epidemiological evidence / animal studies / limitations in exposure assessment.

****HHS Questions:**** Q10, Q12, Q13, Q16; also relevant to questions addressing RF health research and evidence evaluation.

****Dated:**** February 2020.

****Exposure:**** Review of peer-reviewed animal (in vivo) studies published January 2008–August 2018 and epidemiological studies published January 2008–May 2018, with relevant updates through August 2019, focusing on possible relationships between RF radiation exposure and tumor formation.

****Finding:**** The FDA concluded that the studies reviewed did not provide sufficient evidence to support a causal association between RF radiation exposure and tumor formation. Limitation: The report identifies important challenges in animal-study design and dosimetry, as well as limitations in human exposure assessment, including reliance on self-reported cellphone use as a proxy for RF exposure, recall bias, and difficulty estimating cumulative exposure from multiple sources. Its review period does not include the full body of research published since 2019, and its primary focus is cancer rather than the full range of potential health outcomes.

****Link:**** <https://www.fda.gov/media/135043/download>

REF-0149. Samira Khayat, Hamed Fanaei, Narges Lakzaee, Effects of prenatal mobile phone radiation exposure on MMP9 expression: Implications for inflammation, oxidative stress, and sensory-motor impairment after neonatal hypoxia- ischemia in rats, Toxicology Reports, Volume 11, Pages 378-384 (2023)

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2023

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Samira+Khayat%2C+Hamed+Fanaei%2C+Narges+Lakzaee%2C+Effects+of+prenatal+mobile+phone+radiation+exposure+on+MMP9+expression%3A+Implications+for+inflammation%2C+oxidative+stress%2C+and+sensory-motor+impairment+after+neonatal+hypoxia+ischemia+in+rats%2C+Toxicology+Reports%2C+Volume+11%2C+Pages+378-384+%282023%29>

REF-0150. SAR Investigations on the Exposure Compliance of Wearable Wireless Devices Using Infrared Thermography. Karthik, V. & Rao, T.R. Bioelectromagnetics 39(7):536–545. (2018).

****FCC Topic:**** Wearable wireless devices / exposure compliance.

****HHS Questions:**** Q9, Q12, Q13, Q15, Q16

****Dated:**** 2018.

****Exposure:**** RF emissions from wearable wireless devices operating close to the body.

****Finding:**** Evaluated SAR and exposure compliance of wearable wireless devices and is directly relevant to assessment of devices worn in close proximity to the body.

****Link:**** <https://doi.org/10.1002/bem.22133>

REF-0151. Single strand DNA breaks in rat brain cells exposed to microwave radiation. Paulraj, R., et al. Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis 596(1-2):76-80. (2006).

****FCC Topic:**** Long-term/biological effects (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2006

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Single+strand+DNA+breaks+in+rat+brain+cells+exposed+to+microwave+radiation>

REF-0152. Single- and Double-Strand DNA Breaks in Rat Brain Cells After Acute Exposure to Radiofrequency Electromagnetic Radiation. Lai, H., et al. International Journal of Radiation Biology 69(4):513-521. (2009).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2009

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Single+and+Double+Strand+DNA+Breaks+in+Rat+Brain+Cells+After+Acute+Exposure+to+Radiofrequency+Electromagnetic+Radiation>

REF-0153. Spatial and Temporal Assessment of Radiofrequency Electromagnetic Fields Emitted by Smart Meters and Smart Meter Banks in Urban Environments. (2020).

****FCC Topic:**** Wireless infrastructure / smart-meter exposure characterization.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** 2020.

****Exposure:**** RF emissions from individual smart meters and groups of smart meters.

****Finding:**** Measured spatial field levels and transmission duty cycles at multiple urban locations and demonstrated that a bank of meters can produce a different exposure pattern from an individual meter.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Spatial+and+Temporal+Assessment+of+Radiofrequency+Electromagnetic+Fields+Emitted+by+Smart+Meters+and+Smart+Meter+Banks>

REF-0154. Sperm DNA Damage – The Effect of Stress and Everyday Life Factors. Radwan, M., et al. International Journal of Impotence Research 28(4):148-154. (2016).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2016

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Sperm+DNA+Damage+%E2%80%93+The+Effect+of+Stress+and+Everyday+Life+Factors>

REF-0155. Symptoms, neurological outcomes, and population studies

REF-0156. Testing of behavioral and cognitive development in rats after prenatal exposure to 1800 and 2400 MHz radiofrequency fields. Li, Z.Q., et al. Journal of Radiation Research 61(2):197-206. (2020).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Neurological/cognitive)

HHS Questions: Q6, Q11, Q12, Q13, Q16

Dated: 2020

Exposure: 2400 MHz

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=Testing+of+behavioral+and+cognitive+development+in+rats+after+prenatal+exposure+to+1800+and+2400+MHz+radiofrequency+fields>

REF-0157. The Effect of 2.45 GHz Non-Ionizing Radiation on the Structure and Ultrastructure of The Testis in Juvenile Rats. Simaiova, V., et al. Histology and Histopathology 34(4):18049. (2018).

FCC Topic: Long-term/biological effects (Male fertility)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2018

Exposure: 2.45 GHz

Link: <https://pubmed.ncbi.nlm.nih.gov/?term=The+Effect+of+2>

REF-0158. The Effect of Exposure of Rats During Prenatal Period to Radiation Spreading from Mobile Phones on Renal Development. Bedir, R., et al. Renal Failure 37(2):305-9. (2015).

FCC Topic: Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2015

Exposure: Mobile/cellular RF; frequency not stated in resource

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=The+Effect+of+Exposure+of+Rats+During+Prenatal+Period+to+Radiation+Spreading+from+Mobile+Phones+on+Renal+Development>

REF-0159. The Effect of Wi-Fi Electromagnetic Waves in Unimodal and Multimodal Object Recognition Tasks in Male Rats. Hassanshahi, A., et al. Neurological Sciences 38(6):1069-1076. (2017).

FCC Topic: Long-term/biological effects (Neurological/cognitive)

HHS Questions: Q6, Q11, Q12, Q13, Q16

Dated: 2017

Exposure: Wi-Fi; frequency not stated in resource

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=The+Effect+of+Wi-Fi+Electromagnetic+Waves+in+Unimodal+and+Multimodal+Object+Recognition+Tasks+in+Male+Rats>

REF-0160. The Effects of 900 Megahertz Electromagnetic Field Applied in the Prenatal Period on Spinal Cord Morphology and Motor Behavior in Female Rat Pups. Odaci, E., et al. NeuroQuantology 11(4):573-581. (2013).

FCC Topic: Long-term/biological effects; Children/developmental exposure (Prenatal/fetal)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2013

Exposure: EMF; frequency not stated in resource

Link:

<https://pubmed.ncbi.nlm.nih.gov/?term=The+Effects+of+900+Megahertz+Electromagnetic+Field+Applied+in+the+Prenatal+Period+on+Spinal+Cord+Morphology+and+Motor+Behavior+in+Female+Rat+Pups>

REF-0161. The effects of long-term exposure to a 2450 MHz electromagnetic field on growth and pubertal development in female Wistar rats. Sangun, O., et al. Electromagnetic Biology and Medicine 34(1):63-71. (2013).

FCC Topic: Long-term/biological effects; Testing/exposure characterization (Reproductive)

HHS Questions: Q11, Q12, Q13, Q16

Dated: 2013

****Exposure:**** 2450 MHz

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=The+effects+of+long-term+exposure+to+a+2450+MHz+electromagnetic+field+on+growth+and+pubertal+development+in+female+Wistar+rats>

REF-0162. The Effects of Prenatal Exposure to a 900 Megahertz Electromagnetic Field on Hippocampus Morphology and Learning Behavior in Rat Pups. İkinci, A., et al.

NeuroQuantology 11(4):582-590. (2013)

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2013

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=The+Effects+of+Prenatal+Exposure+to+a+900+Megahertz+Electromagnetic+Field+on+Hippocampus+Morphology+and+Learning+Behavior+in+Rat+Pups>

REF-0163. The Effects of Radiofrequency Electromagnetic Radiation on Sperm Function.

Houston, BJ., et al. Reproduction 152(6):R263-R276. (2016).

****FCC Topic:**** Long-term/biological effects (Male fertility)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=The+Effects+of+Radiofrequency+Radiation+on+Mice+Fetus+Weight%2C+Length+and+Tissues>

REF-0164. The Effects of Radiofrequency Radiation on Mice Fetus Weight, Length and Tissues. Alimohammadi, I., et al. Data in Brief 19:2189-2194. (2018).

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=The+Effects+of+Radiofrequency+Radiation+on+Mice+Fetus+Weight%2C+Length+and+Tissues>

REF-0165. The Sensitivity of Children to Electromagnetic Fields. Kheifets, L., et al. Deventer Journal of Pediatrics 116(2):303-313. (2005).

****FCC Topic:**** Children/developmental exposure (Other health effects)

****HHS Questions:**** Q5, Q7, Q8, Q12, Q13, Q15, Q16

****Dated:**** 2005

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=The+Sensitivity+of+Children+to+Electromagnetic+Fields>

REF-0166. Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. Belpomme, D., et al. Environmental Pollution 242(Part A):643-658. (2018).

****FCC Topic:**** Long-term/biological effects (Cancer, Neurological/cognitive, Reproductive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** Not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Thermal+and+non-thermal+health+effects+of+low+intensity+non-ionizing+radiation%3A+An+international+perspective>

REF-0167. Tomruk, A., Ozgur-Buyukatalay, E., Ozturk, G. G., & Ulusu, N. N. Short-term exposure to radiofrequency radiation and metabolic enzymes' activities during pregnancy and prenatal development. *Electromagnetic Biology and Medicine*, 41(4), 370–378. (2022)

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2022

****Exposure:**** RF; frequency not stated in resource

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/?term=Tomruk%2C+A>

REF-0168. Ultra High Frequency-Electromagnetic Field Irradiation During Pregnancy Leads to an Increase in Erythrocytes Micronuclei Incidence in Rat Offspring. Ferreira, A., et al. *Life Sciences* 80(1):43-50. (2006).

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2006

****Exposure:**** EMF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Ultra+High+Frequency-Electromagnetic+Field+Irradiation+During+Pregnancy+Leads+to+an+Increase+in+Erythrocytes+Micronuclei+Incidence+in+Rat+Offspring>

REF-0169. Use of Laptop Computers Connected to Internet Through Wi-Fi Decreases Human Sperm Motility and Increases Sperm DNA Fragmentation. Avendano, C., et al. *Fertility and Sterility* 97(1):39-45. (2012).

****FCC Topic:**** Long-term/biological effects (Male fertility, Reproductive)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2012

****Exposure:**** Wi-Fi; frequency not stated in resource

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/22112647/>

REF-0170. Use of Mobile Phone During Pregnancy and the Risk of Spontaneous Abortion. Mahmoudabadi, F., et al. *Journal of Environmental Health Science and Engineering* 13:34. (2015).

****FCC Topic:**** Long-term/biological effects (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2015

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Use+of+Mobile+Phone+During+Pregnancy+and+the+Risk+of+Spontaneous+Abortion>

REF-0171. Validity of At Home Model Predictions as a Proxy for Personal Exposure to Radiofrequency Electromagnetic Fields from Mobile Phone Base Stations. Beekhuizen, J., et al. *Environment International*. (2015).

****FCC Topic:**** Exposure assessment / epidemiological exposure modeling.

****HHS Questions:**** Q12, Q15, Q16

****Dated:**** 2015.

****Exposure:**** RF fields from mobile-phone base stations.

****Finding:**** Evaluates whether modeled residential exposure can serve as a proxy for personal exposure and demonstrates the importance of distinguishing modeled residential exposure from actual personal measurements.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Validity+of+at+home+model+predictions+as+a+proxy+for+personal+exposure>

REF-0172. What Evidence Exists on the Impact of Anthropogenic Radiofrequency Electromagnetic Fields on Animals and Plants in the Environment: A Systematic Map. Curry, R., et al. Environmental Evidence. (2024).

****FCC Topic:**** Environmental effects of RF exposure.

****HHS Questions:**** Q17, Q18

****Dated:**** 2024.

****Exposure:**** Anthropogenic RF-EMF in environmental settings.

****Finding:**** Systematic map of 334 studies, including 237 studies involving fauna and 97 involving flora; most were laboratory studies and many used exposures below ICNIRP guidelines. The review identified substantial evidence gaps, particularly for field and ecosystem-level research.

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=What+evidence+exists+on+the+impact+of+anthropogenic+radiofrequency+electromagnetic+fields+on+animals+and+plants+in+the+environment>
REF-0173. WHO International EMF Project. World Health Organization (WHO). (n.d.). The International EMF Project.

****FCC Topic:**** Coordinated scientific assessment / research gaps / international standards / public information.

****HHS Questions:**** Q12, Q13, Q15, Q16; relevance depends on the specific question's focus on research coordination, exposure assessment, or public communication.

****Dated:**** Undated webpage; access; October 10, 2026.

****Exposure:**** Electromagnetic fields across relevant frequency ranges, including RF fields from wireless technologies.

****Finding:**** The project coordinates international scientific work on EMF, supports assessment of scientific evidence, identifies research needs, and provides information relevant to public authorities and communities. It supports the broader rationale for coordinated exposure data collection and research that can inform public-health assessment and policy.

****Link:**** <https://www.who.int/initiatives/the-international-emf-project>

REF-0174. Why children absorb more microwave radiation than adults: The consequences. Morgan, L.L., et al. Journal of Microscopy and Ultrastructure 2(4):197-204. (2014).

****FCC Topic:**** Long-term/biological effects; Children/developmental exposure (Cancer. Other health effects, Neurological/cognitive, Reproductive)

****HHS Questions:**** Q5, Q6, Q7, Q7, Q11, Q12, Q13, Q16

****Dated:**** 2014

****Exposure:**** Not stated in resource

****Link:**** <https://doi.org/10.1016/j.jmau.2014.06.005>

REF-0175. Wi-Fi Electromagnetic Fields Expert Gender Related Alterations of EEG. Maganioti, A., et al. (2010).

****FCC Topic:**** Long-term/biological effects (Neurological/cognitive)

****HHS Questions:**** Q6, Q11, Q12, Q13, Q16

****Dated:**** 2010

****Exposure:**** Wi-Fi; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Wi-Fi+Electromagnetic+Fields+Expert+Gender+Related+Alterations+of+EEG>

REF-0176. Wi-Fi Is an Important Threat to Human Health. Pall, M. Environmental Research 164:405-416. (2018).

****FCC Topic:**** Scientific evidence relevant to reassessment (Other health effects);
Long-term/biological effects (Cancer, Neurological/cognitive, Reproductive)

****HHS Questions:**** Q5, Q6, Q7, Q8, Q11, Q12, Q13, Q16

****Dated:**** 2018

****Exposure:**** Wi-Fi; frequency not stated in resource

****Link:****

<https://pubmed.ncbi.nlm.nih.gov/?term=Wi-Fi+Is+an+Important+Threat+to+Human+Health>
REF-0177. Yousefi, B., Jadidi, M., Nabizadeh, Z. et al. Impairment of Oogenesis and Folliculogenesis in Neonatal Rats after Maternal Exposure to Mobile Phones. *Reprod. Sci.* 32, 2259–2269 (2025).

****FCC Topic:**** Long-term/biological effects; Testing/exposure characterization (Prenatal/fetal)

****HHS Questions:**** Q11, Q12, Q13, Q16

****Dated:**** 2025

****Exposure:**** Mobile/cellular RF; frequency not stated in resource

****Link:**** <https://pubmed.ncbi.nlm.nih.gov/?term=Yousefi%2C+B>