APPENDIX C — SCIENTIFIC REFERENCES REGARDING PEDIATRIC RF/EMF EFFECTS

The following peer-reviewed studies and systematic reviews are relevant to the potential effects of radiofrequency electromagnetic fields ("RF-EMF") on children and adolescents. They include epidemiological studies, prospective cohort studies, controlled experimental studies, exposure-assessment studies, and systematic reviews. The studies report associations or experimentally observed effects involving behavior, cognition, brain activity, headaches, sleep, hearing, neurodevelopment, and other outcomes. The findings are not uniform, and several investigators expressly caution that observational associations do not establish causation. Accordingly, these references are presented as evidence warranting further investigation rather than as proof that RF-EMF exposure causes a particular health outcome in every instance.

A. Systematic Reviews and Evidence Syntheses

1. Lambert Bodewein et al., Systematic Review of the Physiological and Health-Related Effects of Radiofrequency Electromagnetic Field Exposure from Wireless Communication Devices on Children and Adolescents in Experimental and Epidemiological Human Studies, 17 P*LOS ONE* e0268641 (2022), doi:10.1371/journal.pone.0268641, PMID 35648738.

Summary: This systematic review identified 53 human studies involving children and adolescents—42 epidemiological studies and 11 experimental studies—and found reported effects or associations in a subset of the literature, while concluding that the overall evidence was inconsistent and insufficient for a definitive conclusion. The authors emphasized the need for additional high-quality research concerning pediatric RF-EMF exposure. PubMed PMID 35648738.

2. Ishihara, T., Yamazaki, K., Araki, A., Teraoka, Y., Tamura, N., Hikage, T., Omiya, M., Mizuta, M., & Kishi, R. (2020). Exposure to radiofrequency electromagnetic field in the high-frequency band and cognitive function in children and adolescents: A literature review. *International Journal of Environmental Research and Public Health*, 17(24), 9179. https://doi.org/10.3390/ijerph17249179.

Summary: This literature review evaluated 12 studies involving children and adolescents ages 4–17 and reported that a minority of the examined exposure-outcome relationships showed negative associations between RF-EMF exposure and cognitive performance, particularly in studies using objective exposure measurements and involving older children. The authors nevertheless emphasized substantial inconsistency across the literature. PubMed PMID 33302600.

3. Ashrafinia, F., Moeindarbari, S., Razmjouei, P., Ghazanfarpour, M., Najafi, M. N., Moodi Ghalibaf, A. A., & Abdi, F. (2021). Can prenatal and postnatal cell phone exposure increase adverse maternal, infant and child outcomes? *Revista Brasileira de Ginecologia e Obstetrícia*, 43(11), 870–877. https://doi.org/10.1055/s-0041-1736173

Summary: This systematic review reported that studies of younger children frequently produced null findings, while some studies of children ages approximately 7–11 reported increased risks of emotional and behavioral difficulties associated with maternal cellphone exposure; the review characterized the evidence concerning several other developmental outcomes as controversial or inconclusive. PubMed PMID 34872146.

B. Cognition, Brain Function, and Neurodevelopment

4. Alba Cabré-Riera et al., Association Between Estimated Whole-Brain Radiofrequency Electromagnetic Fields Dose and Cognitive Function in Preadolescents and Adolescents, 231 *International Journal of Hygiene and Environmental Health* 113659 (2021), doi:10.1016/j.ijheh.2020.113659, PMID 33221634.

Summary: In population-based birth cohorts, higher estimated whole-brain RF-EMF dose from all assessed sources and from phone calls was associated with lower non-verbal intelligence scores in preadolescents; no association was found for the other cognitive outcomes examined. The authors emphasized the cross-sectional design, small effect sizes, and possibility of chance or reverse causality. PubMed PMID 33221634.

5. Alba Cabré-Riera et al., Estimated Whole-Brain and Lobe-Specific Radiofrequency Electromagnetic Fields Doses and Brain Volumes in Preadolescents, 142 *Environment International* 105808 (2020), doi:10.1016/j.envint.2020.105808, PMID 32554140.

Summary: Among preadolescents ages 9–12, higher estimated RF-EMF dose associated with wireless-internet activities was associated with a smaller caudate volume in one analysis, although most other examined brain-volume measures were not significantly associated with RF-EMF exposure. PubMed PMID 32554140.

6. S. Leung et al., Effects of 2G and 3G Mobile Phones on Performance and Electrophysiology in Adolescents, Young Adults and Older Adults, 122 *Clinical Neurophysiology* 2203–2216 (2011), doi:10.1016/j.clinph.2011.04.006, PMID 21570341.

Summary: In a controlled crossover experiment, 3G exposure was associated with reduced N-back performance in the adolescent subgroup, while 2G and 3G exposure also produced measurable changes in electrophysiological responses. PubMed PMID 21570341.

7. C.M. Krause et al., Mobile Phone Effects on Children's Event-Related Oscillatory EEG During an Auditory Memory Task, 82 *International Journal of Radiation Biology* 443–450 (2006), doi:10.1080/09553000600840922.

Summary: Experimental exposure to a GSM mobile-phone signal produced changes in event-related EEG oscillatory activity in children performing an auditory memory task; the investigators did not, however, characterize the EEG findings as proof of a health impairment.

8. I. Calvente et al., Does Exposure to Environmental Radiofrequency Electromagnetic Fields Cause Cognitive and Behavioral Effects in 10-Year-Old Boys?, 37 *Bioelectromagnetics* 25–36 (2016), doi:10.1002/bem.21951, PMID 26769168.

Summary: Among 123 boys ages 9–11, higher measured environmental RF exposure was associated with lower scores on certain verbal measures and higher scores on several behavioral measures, including internalizing and total-problem measures; the authors cautioned that the findings were insufficient to establish causation. PubMed PMID 26769168.

9. Y.H. Byun et al., Mobile Phone Use, Blood Lead Levels, and Attention Deficit Hyperactivity Symptoms in Children: A Longitudinal Study, 8 *PLOS ONE* e59742 (2013), doi:10.1371/journal.pone.0059742, PMID 23555766.

Summary: In a longitudinal study of 2,422 Korean elementary-school children, mobile-phone voice-call exposure was associated with increased ADHD-symptom risk among children with relatively high blood-lead levels, suggesting a possible interaction between RF-related exposure and another environmental exposure. PubMed PMID 23555766.

C. Behavioral and Emotional Outcomes

10. H.A. Divan et al., Prenatal and Postnatal Exposure to Cell Phone Use and Behavioral Problems in Children, 19 *Epidemiology* 523–529 (2008), doi:10.1097/EDE.0b013e318175dd47, PMID 18467962.

Summary: Among 13,159 children in the Danish National Birth Cohort, prenatal and postnatal cellphone exposure was associated with increased odds of reported behavioral difficulties, including emotional and hyperactivity problems; the authors expressly cautioned that the associations might be noncausal and reflect unmeasured confounding. PubMed PMID 18467962.

11. M. Sudan et al., Prospective Cohort Analysis of Cellphone Use and Emotional and Behavioural Difficulties in Children, 70 *Journal of Epidemiology & Community Health* 1207–1213 (2016), doi:10.1136/jech-2016-207419, PMID 27217533.

Summary: In a prospective cohort analysis, prenatal and postnatal cellphone exposure was associated with increased odds of later emotional and behavioral difficulties among children who had not exhibited such difficulties previously.

12. Laura Birks et al., Maternal Cell Phone Use During Pregnancy and Child Behavioral Problems in Five Birth Cohorts, 104 *Environment International* 122–131 (2017), doi:10.1016/j.envint.2017.03.024, PMID 28392066.

Summary: Across five birth cohorts comprising 83,884 mother-child pairs, higher maternal cellphone use during pregnancy was associated with increased risk of clinical-range hyperactivity/inattention problems in children ages 5–7; the authors

emphasized that uncontrolled confounding could influence the association. PubMed PMID 28392066.

13. M. Guxens et al., Radiofrequency Electromagnetic Fields, Screen Time, and Emotional and Behavioural Problems in 5-Year-Old Children, 222 *International Journal of Hygiene and Environmental Health* 188–194 (2019), doi:10.1016/j.ijheh.2018.09.006, PMID 30314943.

Summary: Higher residential RF-EMF exposure from mobile-phone base stations was associated with increased odds of reported emotional symptoms in 5-year-old children in one analysis, although the authors noted possible residual confounding and reverse causality.

D. Headaches, Symptoms, and General Health

14. M. Sudan et al., Prenatal and Postnatal Cell Phone Exposures and Headaches in Children, 6 *Open Pediatric Medical Journal* 46–52 (2012), doi:10.2174/1874309901206010046, PMID 23750182.

Summary: Among more than 52,000 children, combined prenatal and postnatal cellphone exposure was associated with higher odds of migraine and headache-related symptoms, although the investigators cautioned that the findings might not represent causal effects.

15. C.T. Chiu et al., Mobile Phone Use and Health Symptoms in Children, 114 *Journal of the Formosan Medical Association* 598–604 (2015), doi:10.1016/j.jfma.2014.07.002, PMID 25115529.

Summary: Among Taiwanese children ages 11–15, mobile-phone use was associated with increased odds of headache/migraine and skin itching; the cross-sectional design prevented determination of causality.

16. S. Thomas et al., Exposure to Radio-Frequency Electromagnetic Fields and Behavioural Problems in Bavarian Children and Adolescents, 25 *European Journal of Epidemiology* 135–141 (2010), doi:10.1007/s10654-009-9408-x, PMID 19960235.

Summary: In a population-based study of Bavarian children and adolescents, higher measured RF-EMF exposure was associated with behavioral problems, including conduct problems, with some associations observed at exposure levels below applicable reference levels. PubMed PMID 19960235.

17. S. Heinrich et al., Association Between Exposure to Radiofrequency Electromagnetic Fields Assessed by Dosimetry and Acute Symptoms in Children and Adolescents: A Population Based Cross-Sectional Study, 9 *Environmental Health* 75 (2010), doi:10.1186/1476-069X-9-75, PMID 21108839.

Summary: Using personal RF dosimetry in children and adolescents, the investigators examined associations between objectively measured RF exposure and acute

symptoms and reported associations for certain symptoms, while finding no uniform exposure-response pattern across all outcomes.

18. F. Söderqvist et al., Use of Wireless Telephones and Self-Reported Health Symptoms: A Population-Based Study Among Swedish Adolescents Aged 15–19 Years, 7 *Environmental Health* 18 (2008), doi:10.1186/1476-069X-7-18, PMID 18495003.

Frequent wireless-phone users reported greater tiredness, stress, headache, anxiety, concentration difficulties, sleep disturbance, and poorer perceived health than less frequent users, although the observational design and exploratory analyses limited causal interpretation.

E. Fixed-Site Transmitters and Environmental RF Exposure

19. A. Schoeni et al., Symptoms in Swiss Adolescents in Relation to Exposure from Fixed Site Transmitters: A Prospective Cohort Study, 15 *Environmental Health* 77 (2016), doi:10.1186/s12940-016-0158-4, PMID 27422272.

Summary: Among Swiss adolescents, the highest quartile of modeled RF exposure from fixed-site transmitters was associated with increased odds of tiredness in one analysis, although the authors found no consistent overall pattern and cautioned that the isolated association could have arisen by chance.

F. Hearing

20. M. Sudan et al., Cell Phone Exposures and Hearing Loss in Children in the Danish National Birth Cohort, 27 *Paediatric and Perinatal Epidemiology* 247–257 (2013), doi:10.1111/ppe.12036, PMID 23574412.

Summary: Cellphone use was associated with a modest increase in reported hearing loss among children in several analyses, although the authors emphasized that bias could explain the association and that the study did not establish that cellphone exposure caused hearing loss.

G. Sleep

21. A. Huss et al., Environmental Radiofrequency Electromagnetic Fields Exposure at Home, Mobile and Cordless Phone Use, and Sleep Problems in 7-Year-Old Children, 10 *PLOS ONE* e0139869 (2015), doi:10.1371/journal.pone.0139869, PMID 26509676.

Summary: The study found associations between certain RF exposure measures and sleep-related outcomes in 7-year-old children, including associations involving base-station exposure and mobile-phone use, but the investigators concluded that the overall pattern did not establish RF-EMF itself as the cause of the observed sleep effects.

H. Pediatric Susceptibility and Exposure Assessment

22. L. Kheifets et al., The Sensitivity of Children to Electromagnetic Fields, 116 *Pediatrics* e303–e313 (2005), doi:10.1542/peds.2004-2541.

Summary: This review identified developmental, anatomical, behavioral, and exposure-related characteristics that could make children an important population for separate investigation of electromagnetic-field exposure and potential health effects.

23. Wydaeghe, R., Stroobandt, B., Gallucci, S., Parazzini, M., Tognola, G., Wiart, J., Vermeeren, G., Guxens, M., Tanghe, E., & Joseph, W. (2026). Environmental and auto-induced RF-EMF adult and children far-field exposure simulations between 450 MHz and 26 GHz. *Physics in Medicine & Biology*, 71(17), Article 175006. https://doi.org/10.1088/1361-6560/ae97ac

Summary: Children show 1.5–1.9 times higher whole-body SAR than adults at all sub-6 GHz frequencies. The child models also showed higher brain-to-skin wireless radiation absorption rates than adults at the higher frequencies just below 6 GHz. Simulated 5G beamforming— which focuses 5G signal into a narrow, directed beam—created wireless radiation "hotspots" in the body. At some frequencies, these exceeded absorption limits in both child and adult models, even though the radiation reaching the body met the external exposure limit.

I. Additional Scientific References

The following additional references expand the scientific record concerning pediatric and developmental RF/EMF exposure, age-dependent dosimetry, environmental exposure, epidemiology, and reported health effects.

24. Bandara, P., & Carpenter, D. O. (2018). Planetary electromagnetic pollution: It is time to assess its impact. *The Lancet Planetary Health*, 2(12), e512–e514. https://doi.org/10.1016/S2542-5196(18)30221-3

Summary: This commentary describes the rapid increase in anthropogenic electromagnetic-field exposure and argues that electromagnetic pollution should be evaluated as an environmental health issue.

25. Belpomme, D., Hardell, L., Belyaev, I., Burgio, E., & Carpenter, D. O. (2018). Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. *Environmental Pollution*, 242, 643–658. https://doi.org/10.1016/j.envpol.2018.07.019

Summary: This review examines reported biological and health effects of low-intensity electromagnetic fields, including RF exposure, and discusses evidence concerning cancer, reproduction, neurobehavioral effects, oxidative stress, and electrohypersensitivity.

26. Cabot, E., Christ, A., Bühlmann, B., Zefferer, M., Chavannes, N., Bakker, J. F., van Rhoon, G. C., & Kuster, N. (2014). Quantification of RF-exposure of the fetus using anatomical CAD-models in three different gestational stages. *Health Physics*, 107(5), 369–381. https://doi.org/10.1097/HP.0000000000000129

Summary: Anatomical computational models representing three stages of pregnancy were used to quantify fetal RF exposure, demonstrating that exposure varies with gestational stage, anatomy, and exposure conditions.

27. Carpenter, D. O. (2013). Human disease resulting from exposure to electromagnetic fields. *Reviews on Environmental Health,* 28(4), 159–172. https://doi.org/10.1515/reveh-2013-0016

Summary: This review considers evidence concerning human health effects associated with electromagnetic fields, including RF and extremely low-frequency exposures, and discusses reported disease associations.

28. Christ, A., Gosselin, M.-C., Christopoulou, M., Kühn, S., & Kuster, N. (2010). Age-dependent tissue-specific exposure of cell phone users. *Physics in Medicine & Biology*, 55(7), 1767–1783. https://doi.org/10.1088/0031- 9155/55/7/001

Summary: MRI-based anatomical models of adults and children were used to evaluate age-dependent RF absorption. The study shows that age, anatomy, tissue properties, and phone characteristics affect local absorption, particularly in brain tissues.

29. Directorate-General for Parliamentary Research Services (European Parliament), & Belpoggi, F. (2021). Health impact of 5G: Current state of knowledge of 5G-related carcinogenic and reproductive/developmental hazards as they emerge from epidemiological studies and in vivo experimental studies. *Publications Office of the European Union*. https://www.europarl.europa.eu/RegData/etudes/STUD/2021/690012/EPRS_STU(2021)690012_EN.pdf

Summary: This European Parliament research review summarizes evidence concerning possible carcinogenic and reproductive/developmental hazards associated with 5G and related RF exposures and identifies important evidence gaps.

30. Fernández, C., de Salles, A. A., Sears, M. E., Morris, R. D., & Davis, D. L. (2018). Absorption of wireless radiation in the child versus adult brain and eye from cell phone conversation or virtual reality. *Environmental Research,* 167, 694–699. https://doi.org/10.1016/j.envres.2018.05.013

Summary: Age-specific anatomical modeling found higher local RF absorption in young brains and eyes than in adults under modeled cell-phone and virtual-reality exposure conditions.

31. Fernández-Rodríguez, C. E., De Salles, A. A. A., & Davis, D. L. (2015). Dosimetric simulations of brain absorption of mobile phone radiation–The relationship between psSAR and age. *IEEE Access,* 3, 2425–2430. https://doi.org/10.1109/ACCESS.2015.2502900

Summary: This dosimetric modeling study examined how peak spatial specific absorption rate varies with age and found that age-dependent anatomy can affect brain RF absorption estimates.

32. Ferreira, J., & Almeida de Salles, A. (2015). Specific absorption rate (SAR) in the head of tablet users. In *The 7th IEEE Latin-American Conference on Communications* (LatinCom 2015) (pp. 5–9). CEUR Workshop Proceedings, 1538. http://ceur-ws.org/Vol-1538/paper-02.pdf

Summary: This conference paper evaluates SAR in the head during tablet use and illustrates how device position and use conditions can affect RF absorption.

33. Frank, J. W. (2021). Electromagnetic fields, 5G and health: What about the precautionary principle? *Journal of Epidemiology & Community Health,* 75(6), 562–566. https://doi.org/10.1136/jech-2019-213595

Summary: This essay reviews uncertainties surrounding 5G health assessment, including limited epidemiological evidence specific to 5G and emerging laboratory and epidemiological findings from earlier RF technologies.

34. Gandhi, O. P. (2015). Yes the children are more exposed to radiofrequency energy from mobile telephones than adults. *IEEE Acces*s, 3, 985–988. https://doi.org/10.1109/ACCESS.2015.2438782

Summary: This analysis compares RF exposure characteristics of children and adults using mobile phones and discusses greater absorption in relevant tissues associated with anatomical differences.

35. Gandhi, O. P., Morgan, L. L., de Salles, A. A., Han, Y.-Y., Herberman, R. B., & Davis, D. L. (2012). Exposure limits: The underestimation of absorbed cell phone radiation, especially in children. *Electromagnetic Biology and Medicine,* 31(1), 34–51. https://doi.org/10.3109/15368378.2011.622827

Summary: This paper evaluates limitations of the Specific Anthropomorphic Mannequin model used in cell-phone certification and argues that it can underestimate RF absorption, particularly for children.

36. Hardell, L. (2018). Effects of mobile phones on children's and adolescents' health: A commentary. *Child Development,* 89(1), 137–140. https://doi.org/10.1111/cdev.12831

Summary: This commentary reviews concerns about childhood and adolescent RF exposure and discusses possible implications for brain tumors, cognition, sleep, behavior, and neurological health.

37. International Commission on the Biological Effects of Electromagnetic Fields. (2022). Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: Implications for 5G. *Environmental Health*, 21, 92. https://doi.org/10.1186/s12940-022-00900-9

Summary: This review/commentary examines evidence and assumptions underlying FCC and ICNIRP RF exposure limits and discusses reported biological effects beyond established thermal mechanisms and implications for 5G.

38. Kelley, E., Blank, M., Lai, H., Moskowitz, J., & Havas, M. (2015). International appeal: Scientists call for protection from non-ionizing electromagnetic field exposure. *European Journal of Oncology,* 20, 180–182.

Summary: This published international appeal summarizes concerns expressed by scientists about potential biological and health effects of non-ionizing electromagnetic-field exposure and calls for stronger protective measures and research.

39. Lissak, G. (2018). Adverse physiological and psychological effects of screen time on children and adolescents: Literature review and case study. *Environmental Research*, 164, 149–157. https://doi.org/10.1016/j.envres.2018.01.015

Summary: This review examines health effects associated with intensive screen use in children and adolescents, including sleep, cardiovascular risk factors, psychological effects, and neurological or behavioral outcomes.

40. McCredden, J. E., Cook, N., Weller, S., & Leach, V. (2022). Wireless technology is an environmental stressor requiring new understanding and approaches in health care. *Frontiers in Public Health*, 10, 986315. https://doi.org/10.3389/fpubh.2022.986315

Summary: This review discusses wireless technology as an environmental exposure and surveys reported biological and health effects, including issues relevant to electromagnetic hypersensitivity and clinical care.

41. Miller, A. B., Morgan, L. L., Udasin, I., & Davis, D. L. (2018). Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102). *Environmental Research*, 167, 673–683. https://doi.org/10.1016/j.envres.2018.06.043

Summary: This review updates epidemiological evidence published after the IARC 2011 evaluation of RF radiation and summarizes studies concerning brain and other tumors.

42. Miller, A. B., Sears, M. E., Morgan, L. L., Davis, D. L., Hardell, L., Oremus, M., & Soskolne, C. L. (2019). Risks to health and well-being from radio-frequency radiation emitted by cell phones and other wireless devices. *Frontiers in Public Health*, 7, 223. https://doi.org/10.3389/fpubh.2019.00223

Summary: This review evaluates epidemiological and experimental evidence concerning RF radiation from cell phones and wireless devices, covering cancer, non-cancer outcomes, child development, reproduction, and reported electromagnetic hypersensitivity.

43. Mohammed, B., Jin, J., Abbosh, A. M., Bialkowski, K. S., Manoufali, M., & Crozier, S. (2017). Evaluation of children's exposure to electromagnetic fields of mobile phones using age-specific head models with age-dependent dielectric properties. *IEEE Access*, 5, 27345–27353. https://doi.org/10.1109/ACCESS.2017.2767074

Summary: This computational study uses age-specific head models and age-dependent tissue dielectric properties to evaluate RF exposure from mobile phones and illustrates how anatomy and tissue properties affect exposure estimates.

44. Moon, J.-H. (2020). Health effects of electromagnetic fields on children. *Clinical and Experimental Pediatrics*, 63(11), 422–428. https://doi.org/10.3345/cep.2019.01494

Summary: This pediatric review summarizes research concerning children's exposure to electromagnetic fields and discusses potential effects on the developing nervous system, cognition, behavior, and other outcomes.

45. Redmayne, M., & Johansson, O. (2015). Radiofrequency exposure in young and old: Different sensitivities in light of age-relevant natural differences. *Reviews on Environmental Health*, 30(4), 323–335. https://doi.org/10.1515/reveh-2015-0030

Summary: This review examines age-related biological and physiological differences that may influence responses to RF-EMF exposure and concludes that developmental stage may be relevant to susceptibility.

46. Sage, C., & Burgio, E. (2018). Electromagnetic fields, pulsed radiofrequency radiation, and epigenetics: How wireless technologies may affect childhood development. *Child Development,* 89(1), 129–136. https://doi.org/10.1111/cdev.12824

Summary: This review discusses experimental and mechanistic evidence concerning pulsed RF radiation and epigenetic processes, with attention to possible implications for neurodevelopment, cognition, learning, attention, and behavior.

47. Siervo, B., Morelli, M. S., Landini, L., & Hartwig, V. (2018). Numerical evaluation of human exposure to WiMax patch antenna in tablet or laptop. *Bioelectromagnetics,* 39(5), 414–422. https://doi.org/10.1002/bem.22128

Summary: Finite-difference time-domain modeling evaluated RF exposure from a 3.5-GHz WiMax antenna in adult and child anatomical models; some modeled worst-case configurations produced absorption hotspots in sensitive organs.

48. Wang, J., Fujiwara, O., Kodera, S., & Watanabe, S. (2006). FDTD calculation of whole-body average SAR in adult and child models for frequencies from 30 MHz to 3 GHz. *Physics in Medicine & Biology,* 51(17), 4119–4127. https://doi.org/10.1088/0031-9155/51/17/001

Summary: This finite-difference time-domain study compares whole-body average SAR in adult and child models across 30 MHz to 3 GHz and reports differences relevant to RF exposure-limit assessment.