Evolution, Genetics, and Nature: Implications for Orthodox

GAYLE E. WOLOSCHAK
Northwestern University
Feinberg School of Medicine

In the science-religion community much effort is placed on doing 'evolution apologetics — i.e., defending evolution against creationism or intelligent design or some other form of fundamentalist perspective on human origins. This article will not engage in the usual apologetics as that has been done elsewhere (1–3) in depth.[1] Instead, this work will attempt to discuss evolution from the perspective of the implications it has for how we think about humanity now and in the future.

Life Is That Which Evolves

There are many definitions of life—that which is capable of reproduction, that which can metabolize, etc. One definition that seems fitting in this article is 'that which evolves'. Evolution was first defined in biology as a process by which natural selection chooses those species that are most fit to survive in their current environment. Biological evolution also implies that survival will permit procreation where the next generation will largely resemble the parental organism(s) that survived. The conveyers of evolution are genes, fragments of DNA that code for proteins that function in cells. Changes in genetic material are called mutations. On the level of organism, mutations can be beneficial, harmful, or neutral. Mutations can be beneficial in one environment and harmful in another. At the same time, mutants that are neutral (i.e., convey no advantage or disadvantage in a given environment) remain in the population in silence…and yet at some future time, these neutral mutations could become advantageous or problematic.

On Planet Earth, life became life when I became capable of evolving.[2] It is not known if this is the same on all planets (if there is life on other planets), but on this planet evolution is a pre-requisite for life. Evolution is a natural process, but it is also the reason for other 'natural' processes. Humans reproduce by sexual reproduction because evolution selected for it, and many species reproduce by asexual reproduc-

[1] G. E. Woloschak, 'The Compatibility of the Principles of Evolution with Eastern Orthodoxy', in. *St. Vladimir's Theological Quarterly* 55 (2011): 209–31; Gayle E. Woloschak, 'God of Life: Contemplating Evolution, Ecology, Extinction', in *The Ecumenical Review* 65.1 (2013): 145–59.

[2] Much of the description about evolution comes from textbook and Wikipedia information about evolution. One of the best evolution textbooks is D. Futuyama and M. Kirkpatrick, *Evolution* (Oxford: Oxford Univ. Press, 2018). Wikipedia also has a variety of different websites with accurate information on evolution, mutations, etc.

tion because evolution selected for it. Plants carry out photosynthesis because of evolution, mammals produce milk because of evolution, and every single biological process that occurs on this planet gradually came into being through evolution. Evolution is the underlying principle of all of life on earth and life cannot be imagined without it. Life cannot be understood without understanding evolution; scientists do not like to use the term 'law' when considering scientific principles (because all things must be continuously tested for accuracy). Nevertheless, evolution is one of those principles for which the data are so overwhelming that the fact that evolution occurs cannot be questioned although there can be many issues to be considered about the mechanisms of it.

Often in the Church there is a reverence for what is natural, and yet at the same time Orthodox accept medical treatments that are often 'unnatural'—the use of chemotherapeutic drugs that poison the cancer and poison the body, the use of genetic manipulations, etc. It is important that the Church rise above these natural/unnatural considerations and instead weigh the issues based on love for the other and on ethical expectations with a glance toward '*oikonomia*'. This will be discussed in the remainder of this paper.

Randomness of Evolution

Evolution is driven to a large extent by random mutations that occur and then get selected for or against (or remain neutral). This randomness of mutation induction is essential for evolution because without randomness species would not be able to adapt to a changing environment and the Earth could not sustain life. Many, particularly those in the Church, find it worrisome that randomness plays such an important role in creation, but this should not be surprising. Randomness allows for a creative and dynamic component in the process of creation and is essential not only for the evolution of species but also for the survival of each living organism. Many biological processes that govern our daily life occur through random processes. Among the most important for humans is the mechanism by which the immune system can generate sufficient diversity to fight every infection one might encounter in a lifetime, which involves a random mutation process that allows for millions of different permutations of immune molecules that fight infection to be generated. The most effective for binding to pathogens are selected for in infections. A few humans with diseases where this random process is damaged or nonfunctional in some way die of overwhelming infections unless they are kept in environments where they are unable to encounter infectious agents. Randomness is in-built into evolution and into biological processes as a whole. It is essential for life and without it organisms cannot evolve and species cannot survive. Randomness is a natural process. One can argue, then, that God creates using at least some random processes, although the exact role that God plays in this process may be a mystery.

The concept of natural selection, then, is one that states that nature selects for the organism that is best suited for a particular environment. This does not mean that this is the best possible design that one could develop or the best organism that lives in an environment—just that, of those available, this is the one that is best suited for a particular environment. Evolution can only select from that which exists and not from all variations that could ever exist. This means that often the species that is best suited for an environment is not the first one that is selected: i.e., species that evolve over time may be better suited for the environment than the first organisms that were selected. In addition, this means that many species reach extinction in a changing environment.

Evolution, because it is a random process, is not perfect. Life is not perfect, many aspects of humanity are not well-suited to the lives we live. Humans complain of lower back problems, are vulnerable to infections, and so many more imperfections that make humanity less than ideally suited for our environment. No species is perfectly suited to its environment, and with changing environments even the survivability of a species is short-lived. Evolution selects for those that can survive long enough to reproduce, and beyond that nothing is relevant.

Interplay of Environment and Evolution

An important aspect of evolution is the interplay between evolution and the environment. In other places I have made the point that the relationship between evolution and ecology is so strong that one cannot understand one without the other.[3] Evolution is dependent upon the environment; it is in the context of the environment that natural selection acts and selects for organisms that are best suited for living in it. However, over time environmental changes take place: the temperature in a given place goes up or goes down, sea levels rise or fall, a river dries up or becomes larger. Each change applies new survival pressure on the organisms that inhabit it. With each cycle of change the organisms that are best suited for the new environment survive better than their peers producing offspring that thrives more robustly. For example, as the temperatures warm, the organisms best suited for that location are not the same ones as those that lived in colder temperatures. Sometimes this means that individual organisms or even the entire species die, other times the few of the more aberrant representatives of a particular species survive (along with the genetics that caused it), and still other times organisms that are mobile move to remote locations that matched their original habitat. This close relationship between

[3] This point is made in the following article: Gayle E. Woloschak, 'Perspectives on Orthodoxy, Evolution and Ecology', in *Toward an Ecology of Transfiguration: Orthodox Christian Perspectives on Environment, Nature, and Creation*, ed. John Chryssavgis, Bruce V. Fotz, (New York: Fordham University Press, 2013), 263–75. In fact, the relationship between evolution and ecology is so close that often those that deny evolution also deny that concerns for the environment are important.

environment and evolution can go both ways: as the environment changes so do the organisms that are best suited for the environment, and sometimes the organisms of one species alter the environment. This creates a never-ending cycle of environment as a driver, organism as a driver, environment as a driver, etc. And, to make it more complicated, environment could be a driver for selection in one condition (temperature, for example), while the organism influences the environment from a different angle (pollution, for example) at the same time, making the habitats for itself and other species no longer habitable.

Some changes in the environment can be very dramatic and cause massive species extinctions creating an opening for the development of new species as a result. The early atmosphere of the earth was considered to have been rich in methane and gaseous hydrogen, which was favorable for the prebiotic (before life) synthesis of organic materials on the planet.[4] As blue-green algae evolved and was able to carry out photosynthesis, oxygen was produced; this occurred approximately 2.8 billion years ago. With this major change, the atmosphere of Earth transitioned from a reducing atmosphere, supportive of frugal anaerobic metabolisms suitable only for very small life forms, to an oxidizing atmosphere as exists on Earth today, which can now support large variety of species. Some have claimed that this 'great oxidation event' was one of the most important things to ever happen on this planet. Without it, there could never have been any animals that breathe oxygen: no insects, no fish, and certainly no humans.'[5] This extreme example demonstrates a very dramatic and significant interplay between evolution and environment. Most environment-evolution interfaces are more subtle and require specific study to uncover the roles of each.

Implications of Evolution for New Technologies

Evolution, then, has selected for the species that are best suited for a given environment, and biological processes ongoing in individual specimens of any given species today are those that best suit its survival in today's environment or in recent environments. A compendium of all of these processes is genetically regulated and biological selection of organisms with given traits ensures that genes regulating them persevere in a population. Genetic traits are generally either essential for life or carryovers from previous mutational events that give rise to advantageous or at least neutral mutations. This means that all of the biological processes human beings engage in have allowed our species to thrive until today. These include reproduction, eating and digesting food, the need for water, etc. Our biological existence

[4] 'Reducing atmosphere' from Wikipedia, https://en.wikipedia.org/wiki/Reducing_atmosphere (accessed 10 December 2019)

[5] Presented in the BBC 'Earth series' by Michael Marshall, July 2015. http://www.bbc.com/earth/story/20150701-the-origin-of-the-air-we-breathe (accessed 10 December 2019)

is a result of our species evolution so far. A question that results from this then is how much humanity should be revering our evolution and calling those biological traits that have been most successful so far 'natural', with a corollary that whatever is 'unnatural' today should be morally forbidden simply based on the fact that it was not (yet) selected for by evolution. This question has broad applications to ethical perspectives on 'un-natural acts' such as in vitro fertilization (IVF), genome editing, vaccines, and others.

It should be noted that throughout history, prior to the addition of any new technology to the toolbox of medicine there has always been the argument that the newly added treatment is unnatural. The treatment of infections with antibiotics was unnatural (even if the antibiotics came from fungi or other natural products), treatment of cancers with radiation or chemotherapy was unnatural (even though radiation is natural at least at low doses and many of the most potent chemotherapy drugs come for plants and other natural sources).[6] Cancer therapies were especially difficult because they involved poisoning the cancer and poisoning the body as a result; the use of a poison was definitely unnatural. These all involved therapies that eventually became standard of care, but the initial reactions in the broad community (including many in the Church) were often cautious and many even sought to limit the treatment. Eventually most religious groups, including the Orthodox Church, accepted these technologies as appropriate for the diseases in question. Despite these considerations, there is no doubt that discernment must be used in treating cancer, balancing quality of life and survival.[7] Certainly pastoral discussions often lead to difficult decisions about continuing or stopping therapy decided on a case-by-case basis. There is an underlying attitude today that as technology moves into the future the Church will inevitably begin to accept it slowly and lagging behind the developments. This suggests then that there is an expectation that many questions humanity has about various approaches and their use today will disappear as time passes and the uses of such approaches becomes commonplace.

There are some technologies that have been implemented with very little discussion from the broad community about ethics or appropriateness, and yet they have had a huge impact on human evolution and survival. Among the most important was the development of the Caesarian-section or C-section. When a baby was considered to be breech in the past, the physicians did the best they could but often the child's life was lost in the course of the birth because the baby came through the birth canal in the wrong position. With the advent of C-section surgery, the baby could be removed successfully and the mortality of babies at birth was drastically

[6] https://www.reactgroup.org/toolbox/understand/antibiotics/development-of-antibiotics-as-medicines/ accessed 19 Nov 2019

[7] For a discussion of cancer, evolution, and pastoral concerns see: L. Hummel and G.E. Woloschak, *Chance, Necessity, Love: An Evolutionary Theology of Cancer* (Wipf and Stock, 2017); L. Hummeland G.E. Woloschak, 'Chance, Necessity, Love: An Evolutionary Theology of Cancer', in *Zygon* 51.2 (2016): 293–317.

reduced. Nevertheless, this process was not a natural birth but rather a physician-assisted planned surgical birth. An unexpected consequence of C-sections was the larger head sizes (leading to larger brain capacity) in humans because no longer was head size limited by the size that would fit through the birth canal.[8] C-sections were employed without much thought about unnatural forms of birth, impact on human evolution, or impact on the human population as a whole. Why is this form of birth intervention considered acceptable with little discussion and other types discussed below are controversial and raise red flags, particularly in the Church community?

In Vitro Fertilization and Reproductive Technologies

What is In Vitro Fertilization (IVF)? It is the process of fertilizing an egg (oocyte) removed from a woman and placed in a test tube with sperm and allowing the process of fertilization to take place in the test tube. Usually, the *in vitro* fertilized egg is permitted to divide several times and then is implanted in the womb of a woman who has been made to be pseudo-pregnant (or has the physiologic changes of pregnancy) through the use of hormones. Usually, several such fertilized eggs are implanted in the womb to ensure that at least one will take and that a healthy baby will result. Such IVF-generated embryos cannot develop into a baby unless implanted into a womb, and thus a womb is a prerequisite for human life right now. (Some efforts are underway to create an artificial womb, but this has proven very difficult.)[9]

When it comes to modern technologies, many, particularly officials in the Roman Catholic Church, are opposed to IVF because it allows for an unnatural process (creating embryos by a process that begins in the test tube) that replaces usual sexual reproduction (the form of reproduction as a result of human evolution) as a means of producing offspring. The Orthodox Church has taken a mixed perspective on this with some bishops giving a blessing for IVF in the creation of children for husbands and wives that have 'infertility disorder'. Other bishops as well as the social-moral documents from the Russian Orthodox Church have condemned IVF because it is unnatural and introduces a foreign element in family life. It has been noted that IVF is also a means by which people can 'play God', giving naturally childless couples the opportunity to have children. Whether those opposed to IVF on these grounds know it or not, the natural process that is being lifted up here is that of evolution,

[8] P. Mitterroeker, S.M. Huettegger, B. Fischer, M. and Pavlicev, 'Cliff-edge model of obstetric selection in humans', *Proc. Nat. Academy of Sci USA* (2016) 113: 14680–5. There is ample work in the literature to support this model that C-sections are likely to permit larger head size in humans now but probably even more extensively in the future.

[9] Some of the basics about IVF can be found on the web: https://www.mayoclinic.org/tests-procedures/in-vitro-fertilization/about/pac-20384716#:~:targetText=In%20vitro%20fertilization%20(IVF)%20is,by%20sperm%20in%20a%20lab. Accessed 19 Nov 2019. For an article examining some Orthodox perspectives: G.E. Woloschak, 'In Vitro Fertilization and the Beginning of Human Life', in *The Wheel* 11 (2017): 11–16.

making that which evolution has selected as being 'God-given'. One can argue that new technologies are also God-given, being the result of human intellect and human creativity, both of which are gifts from God.[10] Nevertheless, knowing how to discern proper use of this technology is important as any technology can be used for good or bad, for benefit or for harm. One need only consider cell phone, which can call an emergency vehicle in a health crisis or become addictive and lead to obsessive use, to realize the values and concerns about technologies.

IVF has become common, and it is estimated that there have been at least 8 million IVF children born in the last 40 years with numbers up to 500,000 per year.[11] It has become an accepted technology, the costs have gone down over the years, and more families can afford IVF as an option for pregnancy. Anecdotal evidence suggests that among Orthodox families, few seek the Church and advice from their spiritual fathers prior to going through IVF. While many Orthodox bishops have admitted to giving blessings for IVF (always with the caveat that the egg and sperm come from the parents and that the wife will carry the child; often with the caveat that only a few fertilized eggs be generated in vitro so that there are no left-over embryos). In the beginning, there were concerns that IVF would generate some birth defects that would have been selected against by a natural pregnancy, but this has not been the case.[12]

Where IVF procedures may be drawn into concerns beyond treatment of fertility disorders is in the selection of the characteristics of the child. In parallel with IVF, procedures for the evaluation of nascent embryos were developed and single cell or few cells were extracted (without hurting future development of the embryo) in order to evaluate if all the chromosomes were in place, etc. With the development of rapid genetic testing procedures, we are now capable of establishing whether an embryo would develop into a healthy child or if it would inherit a genetic disorder that one of the parents may have or carry a mutant gene for. This then means that IVF allows 'pro-implantation' genetic testing — allowing development only of those embryos that would not be affected by a genetic disease. While some of the IVF clinics limit their efforts to such testing, others will also allow future parents to decide about other traits of their future offspring such as hair color, eye color, sex, etc. There are companies that advertise services that include not only IVF but also selection of specific one or few of the fertilized embryos with specific traits for implantation into the womb. The Orthodox Church has taken no official position on the selection of traits of offspring, although few if any Orthodox bishops that have given a blessing for IVF would have permitted selection of traits in the offspring.

[10] Several articles on the value of technology as a gift from God can be found in G.E Woloschak, *Faith Science Mystery* (Alhambra, CA: Sebastian Press, 2018).

[11] https://edition.cnn.com/2018/07/03/health/worldwide-ivf-babies-born-study/index.html#:~:targetText=Conception%20through%20science&targetText=The%20presentation%20estimates%20that%20more,2%20million%20treatment%20cycles%20performed. Accessed 19 Nov 2019.

[12] For a discussion of this: https://rscbayarea.com/blog/birth-defects-ivf accessed 19 Nov 2019

One question of course is why parents who are childless would want to select eye color or hair color or even the sex of the offspring. Intention is important here and could be of help in discerning whether trait selection is ethically appropriate. While some examples of trait selection are clearly frivolous: wanting a child that fits their image of a perfect child, etc., others deserve at least a pause. For example, there is one example from the US where a family selected for a second child with the exact type of cell surface proteins that would permit her to be a compatible bone marrow transplant to their older child who was suffering from leukemia. Little work has been done on examining the motives and intentions of the families and on discussing bioethics of this selection from an Orthodox perspective.

Another concern that is likely to alarm many ethicists and theologians is the possibility of creating parthenotes. These would either be embryos from a single ovum that has been forced to double its genetic material with electrical currents, resulting in a child that would contain genetic material from only a single female; or embryos derived from two female oocytes that would contain genetic material from two different females. The goal of these approaches is to develop embryos without the use of sperm. What would be the further destiny of such embryos has not been discussed—one can imagine a wide spectrum of uses and abuses of parthenote babies should they be implanted and brought to term. Human parthenotes have been created at least twice in the test tube but the procedure was stopped at that time.[13] The merging of two oocytes has been difficult to achieve due to factors unknown about the human reproductive process. The merging of two sperm is more difficult to consider predominantly because sperm are streamlined for mobility and contain none of the sub cellular structures (e.g., almost no mitochondria needed for the energy hungry process of rapid cell divisions needed for embryogenesis). While the processes examined here totally overturn evolution by creating children without sexual reproduction or even without using both sexes, it is possible that they will come to pass in the future. Church reflection on this issue would be difficult. As has been noted above, the argument that parthenotes are 'unnatural' may not be sufficient to dismiss this question.

Reproduction by parthenogenesis from a single ovum would be dangerous for humanity from a genetic perspective predominantly because a simple duplication of one set of genes in humans could lead to an enhancement in any problems that involve recessive genes. In the process of merging two cells in reproduction an individual inherits one copy of each gene (in general) from each parent, the likelihood of obtaining one 'regular' gene from one of the parents decreases the danger of developing a genetic disease if genetic material from one of the parents includes a mutant gene. However, if all genetic material of a new embryo came from duplication of a single cell from one person, then a simple duplication of a genome with one bad

[13] For a discussion on human parthenogenesis, a good review is available: G.J. deCarli and T.C. Pereira, 'On human parthenogenesis', in *Medical Hypotheses* 106 (2017): 57-–60

copy would result in an embryo with both bad copies leading to increased disease frequency. This process is called 'loss of heterozygosity'. This would be dangerous for the human population because it would lead to greater frequencies of disease-associated mutations that would normally be diluted out by combining two different genomes from two individuals. If the Church does not argue against single ovum parthenogenesis based on 'unnatural' processes, the introduction of a genomic risk to the human population would be a reason to veto this approach to reproduction.

Gene Editing

Gene editing technology has been revolutionized in recent years with the development of CRISPR, a technique that allows for the editing of a gene with few off-target effects (i.e., no effects on other genes in the genome).[14] The US National Academy of Sciences convened an international committee to examine CRISPR-based gene editing from biomedical, research, and ethical perspectives.[15] This group made recommendations that included at least initially limiting gene editing technology to only somatic cells (cells that make up the body) and waiting until more is known before moving into germ cells (eggs and sperm as well as embryos).[16] Edits in somatic cells come with some risks to the individual, but edited genome of somatic cells will vanish when the person dies. Edits to germ cells can be passed on in the genetic material of the parents to the offspring; any errors that might result in this process could in that case enter the human population for generations with no way to limit it. As yet, CRISPR still comes with some risks and some off-target effects. As this technology becomes perfected, however, risks of adverse effects will go down and the technique can become more generally applicable. Another broad concern about editing germ cells is the time required to follow individuals to be certain that there are no genetic risks; this would involve long-term follow up through multiple generations, an approach that will be difficult using current scientific approaches.

How does CRISPR feed into the evolution issue raised above for IVF? Clearly, evolution has allowed for selection of particular genes, some of which have negative effects, and it is not clear how it would be wrong to eliminate these from the human population. One concern to this approach, however, is that often humanity does not have the scientific understanding as to why particular mutations have been selected for (or against) in a particular environment. One example where there is a scientific

[14] G.E. Woloschak, 'Human Subjects and Human Rights', in *Human v Religious Rights: German and US Exchanges and Their Implications*, ed. G. Roeber (Vandenhoeck and Ruprecht Press, 2019), in press.

[15] National Academies of Science, Engineering and Medicine: Human Genome Editing: Science, Ethics, and Governance (Washington, D. C., 2017). Available at http://www.nap. edu/24623, accessed 19 Nov 2019.

[16] This system was first defined in bacterial systems in the paper Bolotin, A. / Quinquis, B. / Sorokin, A. / Ehrlich, S. D.: Clustered Regularly Interspaced Short Palindrome Repeats (CRISPRs) Have Spacers of Extrachromosomal Origin, in: Microbiology 151/8 (August 2005), 2551–2561. For a brief review of the history of CRISPR, Lander, E. S.: The Heroes of CRISPR, in: Cell 164 (2016), 18–28, is also important.

understanding is sickle cell anemia, where having two mutant copies gives rise to having sickle cell anemia, a disease where those affected die from poor transport of oxygen to the lungs unless they are able to receive frequent blood transfusions. There is very little difference, however, between having two normal genes or having one normal and one mutant genes with regard to oxygen transport. Nevertheless, those individuals that have one normal and one mutant are resistant to certain infections including malaria and some others. Total removal of this gene from the human population might leave an infection-susceptible humanity particularly in areas where malaria predominates.[17] Another recent example that has come up for discussion centers around the BRCA1 gene; when present in two copies, women have a higher risk of developing breast cancer, but when present in one copy, women produce more milk and have improved fertility.[18] Again, would reduction of this gene from the human population affect fertility in some way? What becomes even more difficult is when considering interacting genes: there are many traits that are multi-genic, which means that multiple genes are involved often interacting with each other. These are complex traits and it is hard to pull apart what each gene contributes and even which genes contribute. For example, in the past few years, schizophrenia has been studied genetically, and over 120 genes were found to be related as well as a variety of other interacting genes; only some of the genes were identified.[19] Considering that humans have less than 30,000 genes to conduct all biological processes throughout life, many of our genes act different roles in different biological pathways in different cells of our bodies. According to an estimate from 2011 as many as 17% of all genes involved in complex diseases have functions in more than one biological process.[20] Disruption of one particular gene among these could inadvertently affect a variety of different pathways gene traits.

As a counterbalance to these concerns are individual issues where families have to handle difficult genetic disorders such as Huntington Disease, Muscular Dystrophy, or Cystic Fibrosis, where changes in the somatic cells cannot correct the problems, and germ-line correction becomes the only hope for a cure for these diseases.[21] Genetic counselors, health care providers, and others treating these patients argue strongly that families suffer significantly as a result of these diseases; with a cure in the hands of humanity, they argue strongly that it is unethical to not employ CRISPR germ-line treatments.

[17] C. De Lange, 'How sickle-cell carriers fend off malaria'. *New Scientist* (2011) 2811 taken from *Cell*, (2011) DOI: 10.1016.

[18] F. Kwiatkowski, M. Arbre, Y. Bidet, C. Laquet, N. Uhrhammer, Y.J. Bignon, 'BRCA mutations increase fertility in families at hereditary breast/ovarian risk', in *PLoS One* 10.6 (2015): e0127363

[19] Schizophrenia Working Group of the Psychiatric Genomics Consortium (with over 300 collaborators). Biological insights from 108 schizophrenia-associated genetic loci. Nature (2014) 511: 421–7.

[20] S.Sivakumaran, F. Agakov, E. Theodoratou, J.G. Prendergast, L. Zgaga, T. Manolio, I. Rudan, P. McKeigue, J.F. Wilson, H. Campbell, 'Abundant pleiotropy in human complex diseases and traits', in *Am J Hum Genet.* 89.5 (2011): 607–18.

[21] https://www.labiotech.eu/tops/crispr-technology-cure-disease/ accessed 19 Nov 2019.

What is similar to the IVF discussion above is that evolution acted through natural selection to make the humans of today look and behave as they do in majority and one must ask whether it is suitable for Christians to dismiss those of us who are in minority as non-natural. MUST we accept what evolution has given us (because it is natural, God-given) or can we change it using technology (which is also God-given)? Perhaps in an environment without changes we could settle for genomes that are all the same; in the real life, with the changes that come with time survival of our species may well depend on those who are genetically in minority at present. What is different from the IVF discussion, nevertheless, is the concern about editing genes in the germ line where we do not fully understand the context of particular genes; a gene can cause different changes in different contexts as noted above. Risks inherent in editing genes that are multi-functional may limit the utility of germ-line alterations—but not so much from a fear of doing 'unnatural acts' or tampering with nature as concerns about making changes without knowing all of the consequences.

Gene editing of somatic cells does not have the inherent risks of that of germ-line cells in that the somatic cells will die with the individual. Since genes in the somatic cells came from genes in the germ cells (eggs and sperm) they too are the product of evolution. Prediction of genetic effects in a single individual are often less complicated than prediction of genetic effects on an entire population. It is hard to imagine how the introduction of a new gene or removal of an existing gene might play a role in the population, but within an individual that is slightly easier to discern; the person's entire genome is possible to sequence and the theoretical determination of at least some known genetic interactions would be possible to examine. While one could argue that any gene editing is unnatural, NOT performing gene editing to eliminate diseases is in some ways claiming that human evolution is special and that we should hold it in such high regard that we are willing to sacrifice human health in its honor.

Vaccines

Vaccinations began with Jenner in 1796 and his vaccine to treat the debilitating disease of small pox. This vaccine involved using a modified version of the small pox virus to force a person to create an immune response that would eliminate the true virus from the system.[22] This is a form of selecting the immune system's cells that identify and attack the disease using the complete pool of cells recognizing a wide array of targets generated by this innate random diversity generation process. Selection of cells in order to induce an immune response is something that happens naturally, but in different people this process takes different amount of time. For

[22] Wikipedia has a great deal on the history of the smallpox vaccine: https://en.wikipedia.org/wiki/Smallpox_vaccine#:~:targetText=Smallpox%20vaccine%2C%20the%20first%20successful,cowpox%20protected%20against%20inoculated%20smallpox. Accessed 19 Nov 2019.

some, immunity against certain infectious targets may be so delayed that they would die before immune defense can be mounted. Vaccination speeds the process along and gives the immune system of those who are vaccinated a head start in this fight. Nevertheless, while some may consider this an 'unnatural' approach, it should be mentioned that for any human disease so far, from the Plague to HIV, some individuals have a resistance that has developed through evolution. Through these few individuals and without vaccinations, natural selection would provide that human species continues to exist made of children of those who are resistant to the disease. The process would take a long time and would be accompanied with the death of countless human beings. In essence, vaccines speed up evolution and make a population able to fight infections that would otherwise kill or debilitate a large percentage of the population.

Like most technologies, vaccines were considered unnatural and dangerous, but with time vaccines became more accepted in the population. Vaccines became required in the US with implementation by requiring children to be vaccinated prior to attending schools, and this was effective in limiting diseases in the population: small pox, measles, tetanus, pertussis, mumps, polio, and others. Some of these diseases were close to being eliminated from the human population as a whole. One can claim that with vaccines, humans were modifying evolution by removing certain viruses from the human population. Viruses specific for these vaccines were stored in freezers around the world as a safe-guard for future needed vaccine development and could be available if there was some danger that came about by eliminating these viruses.

In the past few years, some people (including those in the Church) have developed an aversion to vaccines for two main reasons: (1) concerns that vaccines cause autism and other disorders in children and young adults[23] and (2) concerns that the approach for vaccine development requires the use of aborted fetuses. The evidence that vaccines cause autism is not to be found in the academic literature but is based predominantly on anecdotal stories from families of affected children. The entire hypothetical relationship between autism and vaccine use has been debunked repeatedly in the media, the medical and scientific literature, and in major conferences world-wide. Despite these reports, the false idea that vaccines cause autism persists in the minds of many and limits vaccine use. There are several other diseases that have been falsely attributed to vaccines, but autism has been the most prominent.

The second concern has been more difficult to consider. In the world, several cell lines from aborted fetuses are used for development of a few vaccines. In the US and most western countries, the vaccines that require the use of fetal cells are those against rubella, varicella, and hepatitis A. Two fetal cell lines used for production

[23] There are numerous articles on this, a key example: Plotkin, S., Gerber, J., and Offit, P. A. Vaccines and Autism: A Tale of Shifting Hypotheses. Clinical Infectious Diseases (2009) 48(4): 456–61; the article is available for download at: https://academic.oup.com/cid/article/48/4/456/284219 accessed 19 Nov 2019

were derived from cells from two different therapeutic abortions in the 1960s and no new aborted fetuses have been needed since that time. These same cell lines are used to grow all vaccines today. Attempts have been made to use non-fetal cells for the development of the vaccines, but they have not been effective. For this reason, many people, including some Orthodox Christians, have taken a strong stand against vaccine use, which has resulted in outbreaks of measles in a variety of different schools throughout the US and elsewhere. Guarding the public against serious diseases with vaccines does not require that 100% of people be vaccinated because scientists have shown that 'herd immunity' will protect those who are unvaccinated. This means that infection occurs at a lower rate if fewer people can be infected with an organism (i.e., transmission is reduced if there are fewer people to transmit the infection). For different infectious organisms, different percentages of people are required for herd immunity: for measles virus (which spreads quickly), about 90% of people must be immunized while for polio only 80% must be immunized. The large outbreaks of measles in New York City, for example, demonstrates that fewer than 90% of the population has been immunized; measles is a dangerous disease that impacts the entire immune system of the individual and can lead to death.

The Roman Catholic Church has taken the position that, while the use of aborted fetuses is not appropriate or ethical, two factors influence their approval of vaccines: that the vaccines save countless lives and that no new aborted fetuses are being used for this work.[24] Most Orthodox bishops have taken a position that echoes the comments of the Roman Catholic Church (although this has not been any type of official pronouncement) supporting the use of vaccines with the caveat that no new aborted fetuses will be used. Despite these positive reflections, some attitudes have remained intransigent and difficult to change. These arguments are not based in thinking that the vaccine is unnatural but rather the concept that abortion is wrong and therefore the use of aborted fetuses is wrong. Orthodox parishes and schools have struggled with parental concerns about the use of vaccines.

It is not clear what can be done to remedy these concerns. The first concern (autism) is based on misrepresentations in sensationalist media and can perhaps be handled with the education of the public. The second, however, must reside in the domain of the bishops who can perhaps allay ethical concerns about vaccines and their development. Pious Christian concerns need to be weighed against the public good gained from vaccination through the release of official pronouncements in order to erase any ambiguity on the matter. The number of lives saved from vaccination is estimated to be very high.

[24] A.R. Luno, 'Ethical reflections on vaccines using cells from aborted fetuses', in *National Catholic Bioethics Q* 6.3 (2006); 453–9. A number of hospitals advertise the Roman Catholic position to encourage vaccine use: https://khn.org/morning-breakout/catholic-church-has-given-green-light-to-using-vaccines-derived-from-aborted-fetal-cells-but-one-family-is-still-suing-over-beliefs/

Perspectives

Several key points echo in the comments above relating evolution, technologies, and the Church.

1. The claim that certain processes are 'not natural' in almost all cases relates to our evolution as Homo sapiens. Humans are everything we are biologically because of evolution: our metabolism, our methods of reproduction, our propensity to different infections, our tendency to develop cancer, etc. While many Orthodox claim that that what is natural is what is right, natural is in these cases considered that which is apparent in the majority of human population – something that came from natural selection based on our recent and current environment. Making that claim leads to concerns that include too great a reverence for humanity's evolution and ignoring many technological procedures that are commonly used and are not challenged by the Church.
2. There are valid reasons to limit the use of certain applications of technology, many of which involve concerns about how a technology might impact the biological future and safety of humanity as a population. The ethical consideration of technologies should always include some discussion about how humanity's future could be impacted. It is the responsibility of this generation to safeguard the future ones.
3. Technologies that are used must provide benefit and not be used frivolously or for causes where alternative treatments are available. They should save lives or provide for some treatment for conditions with no other approach for therapy. Special care must be taken when limiting interventions for dangerous or debilitating diseases since human lives and families are so severely impacted by these disorders.
4. Decisions of appropriateness of different technologies often require discernment on a case-by-case basis; not all cases of cancer are the same, not all treatments are the same, not all cases of particular diseases are the same. What works for some does not work for all, and decisions about one do not always apply to all.

In conclusion, many in the Church exclaim that they see the mark of 'unnatural' in processes that are not autonomous biological processes, failing to see that our daily lives are already inundated with processes where we 'aid nature' with such health interventions as C-section or tooth cleaning. We should not forget that many Neanderthal remains show signs of death from jaw inflammation from bad teeth. Many also find the 'unnatural' in fellow human beings who diverge from the average because of their looks or behavior or any other non-majority feature. In this case – we need to remember evolution and from two different angles. First — we are all members of our species and a new disease without a vaccine or swift climate change may quickly change the odds for survival of those of us who are currently

in majority. Secondly — we recognize as 'natural' simply that which is currently most prevalent in our species because evolution has favored it so far. However, the human species is capable of more than reproduction and if we are children of God, he probably appreciates more than our procreation.