Columbia Science Review

Lactase Persistence
Genetic mutations for the enjoyment of Dairy

Birth Order
Effects on personality and intelligence

The Life and Death of Stars
The beauty of supernovas

Sleepy Time
The science behind naps
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Covers Picture: An angiogram of a healthy human heart. Doctors use angiograms, also known as arteriogram x-rays, to diagnose and determine treatment for coronary artery diseases as blockages of either the left or right coronary artery could lead to a heart attack. (See Healing the Heart, pg 10, for more information) Photograph by SPL/Photo Researchers, Inc.

Editor’s Letter

In every issue of the Columbia Science Review, we aim to present engaging articles on developing areas of research and demonstrate the relevance of science and technology in our daily lives. This issue is no exception, as it covers many exciting topics in science, including the emerging field of neuroengineering and the technology behind invisibility. But how do they affect your life?

I’m going to venture out on a limb and assume that very few of you are epileptic, have had a heart attack, suffer from trigeminal neuralgia, use alternative medicine, have an implanted tracking microchip, and dream of being invisible. Not every article will be directly applicable to your life. But the scope of these articles is broad enough to engage everyone. Many of us are familiar with Harry Potter’s invisibility cloak, enjoy art, and/or know someone suffering from a mental disease or heart disease. From this issue, hopefully you will learn a little more about these topics and gain a better understanding of the work and research behind them, as well as the social, political, and ethical issues surrounding them. Some articles may answer questions you’ve had and raise even more. I hope these articles will spark your curiosity for science and all its implications.

Ying C. Li
Editor-in-Chief

President’s Letter

Many historic lessons were obtained through tremendous sacrifice. Such as eating food— if something is poisonous, we all seem to know it. It is common sense. But in the past many people must have eaten this food and died so that now we know better. There I think the first person who ate crabs was admirable. If not a hero, who would dare eat such creatures? Since someone ate crabs, others must have eaten spiders as well. However, they were not tasty. So afterwards people stopped eating them. Those people also deserve our heartfelt gratitude. – Lu Xun (1881-1936)

Since 2004 the Columbia Science Review has been following the frontiers of scientific advances both within the Columbia community and throughout the world. In my last semester at Columbia, I want to give thanks to those scientists who stand at the forefront, allowing the rest of us to benefit from their dedication and insight. Some were martyrs, such as Rosalind Franklin, who died at the age of 37 to ovarian cancer from overexposure to x-rays. Others have suffered tremendous pain in order to stand firm in their own beliefs, such as renowned Galileo Galilei, the father of modern science, who was forced under house arrest for the last years of his life on charge of heresy. There are still millions of more scientists, philosophers, and thinkers who have dedicated their entire lives to research and to better understanding the world. Finally let’s not forget all the young scientists who dedicate hours of their time to the lab, running experiments, analyzing data, and writing articles—the same ones who contribute to our publication.

Ying C. Li
Editor-in-Chief

Shelly Zhu
President
A Belgian patient who has been in a vegetative state after a car accident 5 years ago has defied the expectations of doctors by showing signs of basic thought. People in vegetative states are awake but don’t voluntarily respond to stimuli. Recovery from this condition after 12 months is extremely unusual. This condition is different from coma patients who are not awake. Defying all odds, this patient has had his responses to simple ‘yes’ or ‘no’ questions measured by brain imaging techniques. His brain activity, when asked ‘yes’ or ‘no’ questions, appears similar to that of a normal person performing the same task. This discovery, though groundbreaking, is still extremely rare in patients who are diagnosed as being in a ‘vegetative state’. However, this new discovery exposes the problems with how we diagnose ‘vegetative state’ and pushes the limits of the ethics of end of life treatment and what we consider death.

Andrew Whiten and Carel van Schaik define a behavioral tradition as “a distinctive behavior pattern shared by two or more individuals in a social unit, which persists over time and that new practitioners acquire in part through socially-aided learning.” After controlling for environmentally and genetically determined behaviors, they identified 28 such traditions among orangutans. These include building a second nest above the primary nest during rain or bright sunshine, wiping their faces with leaves, and using leaves to pad the hands when handling spiny fruit. They also found 39 traditions among chimpanzees, including cracking open nuts with stones, holding hands while grooming, and coordinated hunting. Furthermore, different groups often perform similar behaviors differently. For example, chimps in one group might fully clasp hands while grooming, whereas those of a neighboring group might only touch wrists. These distinctive behavioral patterns mirror the diversity of human cultures.

In spite of centuries of evolving to get bigger, sheep in Scotland have started shrinking. Bigger sheep are more able to survive the bitter cold of winter, so most of the big babies survive, and many of the small babies die off. However, as increasing CO₂ concentrations in the atmosphere make winters warmer, more vegetation is able to grow through-out the winter. More vegetation means plentiful food, so even the smaller, more vulnerable sheep are able to get enough to eat. Climate change is a powerful force that can affect lots of different, interconnected aspects of our world. Even a small change in temperature can change where and how well plants grow, which in turn can affect animals, land erosion, and agriculture. It can even trump evolution.

Despite numerous artists’ depictions of vibrantly colored dinosaurs in the past, they have never been based on scientific fact until now. The fantasy of a world teeming with brightly striped dinosaurs of an array of colors has finally come to life with a recent study conducted by a team of British and Chinese researchers. In 1996, whisker-like structures were found on a small theropod, known as Sinosauropteryx, but there was doubt as to whether or not they were truly feathers. After examining numerous other theropod fossils, this 2010 study of early Cretaceous fossils from 120 to 131 million years ago has determined that these filaments are indeed feathers and they contain melanosomes, which are organelles that produce color. These scientists have identified the color pattern of the tail of the Sinosauropteryx to have a reddish tint with alternating white areas. The findings from this study allow for future color patterns to be identified from the analysis of dinosaur fossils and give insight into the true color of creatures before our time.
Can a wireless gadget so commonplace in this electronic era cause brain tumors? While the probability of getting cancer is low, you should still be aware of the potential health hazards that cell phones may pose.

Cellular telephones emit a type of wave called radio-frequency energy (RF). Most of the RF energy is produced through its antenna, which you normally place very close to your head when you are talking on the phone. Distance is an important factor for the amount of RF absorption. With increasing distance between the antenna and the user, the amount of RF energy absorbed by a person decreases significantly. The intensity of RF also depends on the phone. Distance is an important factor for the amount of RF energy absorbed by a person decreases significantly. The intensity of RF also depends on the phone. Distance is an important factor for the amount of RF energy absorbed by a person decreases significantly. The intensity of RF also depends on the phone.

Short-term studies have found little or no correlation between cell phone use and tumor development. However, several long-term studies in Denmark, Finland, Norway, Sweden, and the United Kingdom have shown that the risk of cancer is increased for cancer patients who have been using cell phones. A more extensive study of over 400,000 people in Denmark tried to link cell phone use to increased cancer risks by looking at how many people with cell phone subscriptions were listed in the Danish Cancer Society as having brain tumors. Surprisingly, results indicated that there is no association between cell phone use and tumors such as glioma or acoustic neuroma, even among users who have subscribed for ten or more years.

The study results are inconsistent because the time interval between exposure and onset is long. Researchers also face the challenge of finding test subjects who consistently use their cellular phones for decades. Another cause could be reporting bias because in many cases, subjects are more likely to report cell phone use after they are diagnosed with cancer.

Further research is underway to find more reliable results. Meanwhile, another interesting frontier to pursue is the effect of RF energy on children whose nervous systems are still developing. Would brain development be hindered if children started chatting on their phones? Until more definitive research is published, it might just be a good idea for you to figure out the mysterious workings of those ROLM phones.
An early lunar outpost design based on a module design. A connecting tunnel to the left permits the outpost module to connect to landers, rovers or other modules.

Concept: NASA (1990)

space colonization

daniel sims
The idea of space settlement, more often called space colonization, is not a new one. It was originally brought up in the book "The Brick Moon", written by Edward Everett Hale in 1869. However, the idea of space settlement did not become mainstream until the Apollo program showed that humans could set foot on other planets. During this program, men like Gerard K. O'Neill wrote books like "The High Frontier: Human Colonies in Space" which gave credibility to this seemingly impossible dream. Support for space habitation strengthened throughout the "70s and "80s. In fact, support was so strong that Congress passed the Space Settlement Act of 1988. In this bill, space settlement was declared "a long-range objective of the American space program." In addition to that, "once every two years...the National Aeronautics and Space Administration (NASA) has to submit a report to the President and to Congress which analyzes ways in which current science and technology can be applied to the establishment of space settlements." And it identifies scientific and technological capacity for establishing space settlements including a description of what steps must be taken to develop such capacity." Yes, Congress actually passed a law saying we need to inhabit space. Despite this active work on space habitation, I am not currently sipping some sort of blended fruit drink made from moon-fruits in a moon resort and playing moon golf. What's going on? Why is this so hard? Where on Earth is the sun, humans living in space will have increased warning of solar storms and could seek shelter.

OBSTACLE 1: LAUNCH COSTS
In his Technology, Entertainment and Design conference talk, Peter Diamandis, the founder and chairman of the X PRIZE Foundation, gave his analysis of launch costs. He found that it should only cost about $100 to send a person in a space suit into space. $100 is cheap as dirt, yet it still makes launching people to space unaffordable. Despite this, we still see people like the Estonian Zenit 2 at $1,404. And that is per pound. What's going on? Why is this so hard? Where on Earth is my moon colony?

OBSTACLE 2: RADIATION
Current spaceship design would be deadly if applied to space habitation.

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OBSTACLE 3: LIFE SUPPORT
One of the ultimate ways to gain a life support system of Earth is to terraform planets. Literally, you force another planet's environment to mimic Earth's. Many think it is possible to dump enough greenhouse gases into Mars' atmosphere to warm it. This will produce a second Earth by warming up the atmosphere to allow water to flow freely. Once this is done, chemical processes will take over, finishing the transformation. This will then allow for oxygen producing plants to be placed on Mars.

The current system for producing oxygen is recycling old air by removing the CO2, with lithium hydroxide canisters. The chemical reaction that occurs produces oxygen which the astronauts can breathe. This is not the self-sustaining technology. Canisters have to be brought up to replace the depleted lithium hydroxide. Currently human waste is tossed overboard in unmanned vehicles that burn up in the atmosphere (that shooting star isn't a shooting star) and the mission's food is carried into space with the team.

The balancing point would not be a technological solution, it would be a natural one. Space colonies would have ample green space. This would not only produce the food the settlers need, but oxygen as well. Human waste can be effectively dealt with by reusing it as fertilizer. Further increasing the life support system's efficiency.

OBSTACLE 4: HUMAN FACTORS
Biosphere 2 was a sealed structure that simulated the Earth. This independent ecological system failed to support life and sustain itself. Some of the problems that plagued Biosphere 2 will be the same problems that affect space habitats. One issue is that humans are simply not the best decision makers under stress. However, we can learn from the Biosphere 2 experiment mistakes and improve on it.

There will also be tension between Earth and the space colony. Different cultures will emerge out of this effort and they will most likely have conflicting ideas. We already see this in the conflicts between ground control and the astronauts on current space missions. Extensive training will have to be done to avoid this problem, but ultimately, Earth will have to have a loose grip on its habitations.

Noise will also be an issue, since it generates stress. However, this isn't a problem on Skylab, an early space station, "because of the low air pressure inside that made it necessary for astronauts to shout in close proximity to one another to be heard". Since a space colony, like Skylab, is a sealed system, we can play around with the air pressure to lower noise level.

OBSTACLE 5: GRAVITY
Alas, it is not all fun and games when the gravity goes away. The human body in space suffers greatly for the ability to do gymnastic moves with ease. A human's bones and muscles will often wear down in micro-gravity. However, we can simulate gravity in space.

If you have been to a theme park you will have come across an artificial gravity generator. On this attraction you are strapped into a drum like machine that rotates at high speeds. Soon after the machine starts up you start feeling pressure on your chest and eventually you can't even lift up your arms. This effect can be used in a space colony. A structure with a radius of about a mile can rotate at one revolution per minute and simulate Earth's gravitational pull. 3G. However, this structure would be massive, larger than anything we have ever built in space. But, you can build a colony with a radius less than 1 mile, with reducing costs. This would require higher RPMs, which increases personal discomfort. However, the MIT man-vehicle lab found that people can adjust to RPMs up to 30 RPM. It has also been suggested that one could use a medieval torture-esque device: a spinning bed called a Short-Radius Centrifuge.

CONCLUSION
We can achieve space habitation. There is a huge potential for a price decrease in launch costs. Better materials and better space ship designs will block radiation. Life support systems will become self-supporting and we can generate gravity. Through training, we can overcome some human limitations. Yes, there are a million reasons for one to oppose space colonization and there will be many obstacles to overcome in addition to the five listed here. However, if we achieve space settlement, society will be fundamentally changed, just like when the transistor was developed. The Space Settlement Act of 1988 puts it nicely. "The extension of human life beyond Earth's atmosphere for the purposes of advancing science, exploration, and development will enhance the general welfare on Earth."
Data is becoming free to the world. The RCSB Protein Database (PDB) lets anyone with internet access view millions of x-ray crystallography plots of proteins collected by biochemical researchers worldwide. The National Institutes of Health (NIH) have a protein bank with genotypes of millions of different proteins from a myriad animals. The human genome has been free for anyone to study for years—the answer engine, Wolfram Alpha has a feature where it will try to match any sequence of A’s, T’s, C’s, and G’s with the human genome, from any computer in the world, in seconds. And there are thousands of specialized, free, and open source applications that can be used to analyze all of this data in any number of different ways. One can now make scientific breakthroughs with a laptop and use methods of analysis that scientists would have killed for even twenty years ago. However, while data is largely going free, many research journals are accessible on a subscription-only basis. What use are the most sophisticated techniques, and all of the requisite data, if one analyzes it only to find that the paper has already been published?
and the biggest of the physics journals, but still could not afford access to all the journals that Grabois wanted to use for his summer research project in neuroscience.

In response to scientists’ needs, there has been a movement towards open access journals, which are free for anyone to read. There are now over 4,000 open access journals in existence. Even though these journals are free for the reader, “Open access does not conflict with quality in research, and it does not conflict with peer review,” said Jim Neal, vice president for information services and university librarian at Columbia. In 2005, the Columbia University Senate officially endorsed open access, and according to Rebecca Kennison, director of the Center for Digital Research and Scholarship at Columbia, open access is here to stay. "The trend is for more and more among junior scholars and researchers is that they are convinced that this is the way things can and should be," said Kennison.

Due to the advent of search engines, open access journals have been able to make a big impact in the scientific community, and fast. In 2003, Public Library of Science (PLoS) Biology was set up as a competitor to Nature, Cell, and Science, the big three in science publishing. Today, PLoS is the highest rated journal, in the field of Biology in ISI impact factor, which is roughly a measure of how many times articles within a journal are cited. According to Kennison, in addition to garnering more citations for authors, open access journals are myriad and evolving—for example, Scientific Journals International (SJI) has made its editing and peer-review processes volunteer-based but still rigorous, which allows SJI to charge processing fees on a sliding scale, according to authors’ budgets. Universities are also stepping in to foot the bill—in 2010, Columbia University plans to sign on to the Harvard compact, in which Columbia would agree to pay processing fees for any Columbia University scholar who publishes in an open access journal, if the research grant does not cover the processing fees. Some research grants now do cover processing fees–most notably, all research funded by the National Institutes of Health (NIH) is mandated to be on the internet for free, as of April 2008.

What does a world look like in which all research is freely available? Kennison predicts an “increasing speed of discovery—you don’t have to reduplicate peoples’ work because you have that information.” Neal sees a movement towards “open data,” in which data is made freely available? Kennison predicts an “increasing speed of discovery—you don’t have to reduplicate peoples’ work because you have that information.” Neal sees a movement towards “open data,” in which data is made freely available not only after the completion of a research project, but as the project is still ongoing. Kennison foresees that prestige and tenuring decisions will be determined not only by getting articles published, but by producing useful datasets. All of this will be motivated by "the needs of global science," said Neal. As collaborations among scientists become increasingly complex, spanning continents and disciplines, scientists may be ready to share like never before.

While open access journals have been a boon to scientists, there is still the question of who pays the bills. Many journals charge processing fees, in which authors pay the costs of editing and publication. Processing fees allow an open access journal, like PLoS Biology to hire a dedicated, professional editing staff. Business models for open access journals vary, but many are sustainable through grants from governments, funders, and/or subscription fees from researchers who read the journals. According to Kennison, “these are the journals that pay the bills.”

A telomere, the portion of DNA at the end of a chromosome, was discovered by Hermann Muller and Barbara McClintock to prevent the attachment of chromosomes at certain points. Using Tetrahymena thermophila as a vehicle, Blackburn isolated the CCCCAC segment at the end of chromosomes, and thus extending their length of the telomeres; Szostak then injected CCCCAC into a linear DNA molecule (mini-chromosome) in yeast cells, leading to the discovery that the telomere protects the microchromosomes from degradation. Greider and Blackburn then discovered the enzyme telomerase—containing Blackburn’s CCCCAC segment that guides and completes the construction of telomere DNA. Greider and Szostak collectively discovered the telomerase’s protective role in attracting certain proteins to cover the ends of DNA strands reduces senescence (the inability of old diploid cells to divide further past a certain number of divisions) and damage to the chromosome.

The telomere’s ability to preserve chromosomal DNA is important in its application to cancerous cells, which can divide without disturbing the original length of the telomeres and thus extending their lifespan. Solid tumors, especially those of acute and chronic leukemia, have been found to cause certain forms of congenital aplastic anemia, in which not enough blood cells are produced. As a result, patients with congenital aplastic anemia are often tired, weak, and short of breath. In contrast, truly defective telomeres which lead to too few cell divisions in bone marrow stem cells have been found to cause a severe shortage of red blood cells, anemia.

Telomerase is not perfect; it can make inaccurate additions to breaks in DNA. The enzyme is supervised by the DNA damage signaling mechanism in occurrences of double breaks in DNA through P53 phosphorylation. In contrast, truly defective telomeres which lead to too few cell divisions in bone marrow stem cells have been found to cause a severe shortage of red blood cells, anemia.

Telomerase influences the regeneration of beta cells that helps prevent the onset of overt diabetes.

The research of Blackburn, Greider, and Szostak not only introduced the scientific community to another dimension of DNA as a transmitter of information, but also set the stage for the development of treatments aimed at the process of DNA replication. As Blackburn mentions in an interview, it is indeed amazing that “the cell actually devises all sorts of machinery to make sure that never goes wrong, or goes wrong as little as possible.”
When we think of our universe, one of the first things we picture are stars. It is our own star, the Sun, which allows Earth and its life to exist. The millions of stars we can see in the night sky have inspired wonder in humans for innumerable generations, leading to the development of astrology, and later, scientific investigations through astronomy.
The sky is filled with thousands of stars which seem to appear the same night after night. This is because the life of a star is measured in millions or even billions of years, whereas our lifetimes are just a few decades. Humans have not existed long enough to watch a single star go from birth to death. Despite their seemingly static nature, stars have complex lifecycles.

The formation of a star begins when a cloud of cold gas begins to contract. Over thousands of years, the center of this cloud becomes denser and hotter as it becomes more compact. Eventually, this core of gas (mostly hydrogen, with some helium) reaches a density and temperature so that nuclear fusion (the conversion of hydrogen into helium) becomes possible. This releases vast amounts of energy, and once the outward force of the fusion and the inward force of gravity balance each other out, a star is formed.

After birth, stars are called main-sequence stars and will spend about 85-90% of their lives like this. Our Sun is one such star. The time a star remains on the main-sequence depends on its mass. The more massive a star, the shorter amount of time it will spend on the main-sequence, with the most massive stars burning out in only millions of years, instead of billions. The Sun will spend a total of about 10 billion years like this, so at 4.5 billion years old, it is already about halfway through this phase of its life. A star’s mass is also important in determining the later stages of its life.

Main-sequence stars whose mass is less than that of the sun are called dwarfs, with the most numerous type being red-dwarfs. They have masses from 0.075 to 0.5 the mass of the sun. These stars are the most common in the universe because their small masses mean that they are the easiest to form and that they live the longest. Their small size allows red-dwarfs to be convective, instead of radiative, so helium does not build up inside the their core. Because of this, a red-dwarf just becomes dimmer as its life progresses, eventually cooling into a black-dwarf. However, since this process takes longer than the current age of our universe, black dwarfs do not yet exist.

If a main-sequence star is similar in mass to our Sun (from about 0.5 to 6 times the Sun’s mass), it undergoes a more exciting transformation. Once the hydrogen fuel runs out, helium to carbon fusion begins, the outer layers of the star begin to expand, and the star turns red, giving these stars the name red-giants. Most red-giants do not have sufficient mass to fuse carbon into heavier elements, so once the helium runs out, fusion ceases. As the outer layers of these stars are blown off, beautiful planetary nebulae are created. With fusion halted, gravity again begins to compress the star, just as it did at birth. After this process is completed, all that is left of the star is a hot and dense core, made mostly of carbon and oxygen, called a white-dwarf. Most white-dwarfs are about the size of Earth. Like red-dwarfs, white-dwarfs will slowly cool off into black-dwarfs.

Main-sequence stars with masses 10 to 70 times greater than the sun will become giants. The difference between red-giants and these stars is that these have enough mass to fuse carbon into iron (through a complicated process involving other elements) once they run out of helium. This fusion will further increase their volume, creating either a red or blue supergiant. These stars’ large masses make them extremely unstable and their “deaths” cause some of the most exciting phenomena in the universe.

Once these giants run out of carbon to fuse, the end is imminent. This is because the laws of physics do not allow energy to be released by the fusion of iron. The star then has no way to counteract the force of gravity, and begins collapsing again. Eventually, the core of the star is so dense that subatomic particles are pushed almost to the point of touching, and the core becomes a solid mass of neutrons. The outer layers of the star, as they also continue to collapse, hit the now solid core and bounce off, producing a supernova explosion. The energy of a supernova explosion is so great that all elements heavier than iron are created here. The luminosity of a supernova explosion can temporarily be brighter than the luminosity of the galaxy where it is located.

The next stage of the star’s life is also mass dependent. For stars with masses 20 times that of our Sun or less, the core remains a dense ball of neutrons, called a neutron star. These stars are extremely small, with a diameter of only about 20 kilometers. Certain neutron stars can have interesting properties. One type of neutron star, called pulsars, emit thin beams of radiation from the top and bottom of their axis of rotation. If Earth happens to lie in the line of sight of one of these beams, we will see the radiation from the star pulse.

However, when a giant star with a mass more than 20 times the mass of our Sun collapses, not even subatomic particles can get in the way. Instead of just remaining a dense ball of neutrons, the stars core continues collapsing. Eventually, the core becomes so dense that it severely warps the very fabric of space-time, forming a black hole. This means that all the mass of the star has been compressed into a point of almost infinite density. This creates a gravitational field so strong that even light, with the fastest speed in the universe, cannot escape its grasp.

Their humble beginnings as clouds hide the importance stars have in our universe. They are a source of light and life. Being the right distance from our Sun allows the Earth to harbor many different life-forms. Although we have not yet discovered life on other worlds, there are hundreds of billions of stars in the Milky Way galaxy alone, and at least one-hundred billion galaxies in our observable universe. Hopefully a few of those stars support Earth-like planets, inhabited with intelligent creatures who also look up at the sky and ask questions about the stars.
The vast majority of mammals. And a minority occurrence, scientifically it is probably more lactose, a type of sugar found in milk. Although lactose intolerance is perceived in our modern society as a genetic disorder and a minority occurrence, scientifically it is probably more accurate to describe lactose intolerance as a lack of a genetic condition, since lactose intolerance is the standard condition for the vast majority of mammals.

Infant mammals produce large amounts of lactase, but lactase production generally declines after weaning since most mammals do not consume milk as an adult. This decline in production is regulated by the lactase gene (LCT), which is responsible for altering the amount of lactase proteins produced in cells in the digestive tract. Lactose tolerance, known as lactase persistence, arises when a mutation in LCT causes the gene to fail to decrease lactase production after weaning. Most modern human populations contain small numbers of lactase persistence adults. For the majority of human populations, as for the majority of all mammalian populations, generally lactase persistence individuals are a minority. Lactase persistence is common in northwest Europe, particularly Sweden and Denmark, and declines in frequency in southern and eastern Europe. It is also common in northern India, as well as among pastoralists of Arabia and Africa, although there is evidence to suggest that different mutations are responsible for lactase persistence among different groups.

**Point Mutations Cause Lactase Persistence**

The most well studied mutation causing lactase persistence is the one responsible for lactase persistence among most Europeans, West Asian, and North African populations, which involves a single base in LCT. This mutation is known as C/T -13910. C/T refers to a change from the base cytosine to the base thymine, and -13910 refers to the location on the gene on which the change took place. Studies have found that the C/T -13910 mutation correlates perfectly with lactase persistence among a sample of native residents of Finland and probably among other northern European populations as well.

**Evolutionary Origins of Lactase Persistence**

Many attempts have been made to identify the origin of lactase persistence among humans. The lactase persistence trait has undergone exceptionally fast evolution in the past 10,000 years, suggesting that strong selection pressures are acting on lactase. Although 10,000 years may at first seem like a long period of time, it is a mere 5% of the time modern humans have existed and only 0.2% of the time the human lineage generally has existed. Indeed, there is an alternative hypothesis that lactase persistence LCT shows one of the strongest signals of recent positive selection in the human genome. The selection coefficient for lactase persistence, or the measure of evolutionary advantage of the lactase persistence phenotype over non-persistence phenotypes, has been identified by various researchers as somewhere between 2% and 3%, the most common numbers being in the vicinity of 5%.

Strong selection pressures for lactase persistence suggest that there are significant benefits to the phenotype. It allows an individual to take advantage of the ingestion of milk products without negative side effects of lactose intolerance including growth retardation, diarrhea, bloating, and decreased appetite. Milk is rich in calories, calcium, and magnesium. Lactose also has a lower cariogenicity than most other sugars such as sucrose, fructose, and maltose. This means that lactose ferments less easily, causing less tooth decay than other sugars. Lactose can also act as a dietary fiber and enhance absorption of minerals, particularly magnesium and calcium. The combination of substantial benefits of dairy consumption for lactase persistent individuals, and the problems that consumption causes for non-persistent individuals, creates the incredibly strong selection pressures for lactase persistence if adults have access to dairy products.

**Lactase Persistence and Dairying**

Of course, the advantages of dairy would have no bearing on natural selection if human adults did not have access to milk products. The earliest evidence for the use of dairy products by humans comes from milk fat residues found on pottery in Anatolia and the Levant dating to about eight or nine thousand years ago. The development of dairy farming created novel selection pressures on humans who lived in these new dairying societies. This phenomenon by which organisms define and create new selection pressures for themselves and for other organisms is called niche construction. A classic example of this is a beaver dam, which turns a stream into a pond, thus altering the local ecosystem and allowing different species to live in the area. It is this altered environment, not the original environment, in which the selection pressures under which the organisms live are created. Dairying is an excellent example of human niche construction. People living in an environment in which dairy farming has become prevalent will be subject to different selection pressures than those in an environment in which it has not.

The prevailing position on the origin of lactase persistence is that dairying created the selection environment in which lactase persistence was favored and eventually evolved. Some studies suggest that the most ancient of the C/T -13910 mutation corresponds with the origin of dairy farming. Direct evidence for the lack of lactase persistence among pre-dairying communities in Europe also comes from an analysis of DNA from Mesolithic and Neolithic human skeletons, which suggests that prior to the advent of dairying lactase persistence was rare, if not absent, from northern European populations. There is an alternative hypothesis that lactase persistence reached high frequencies in specific regions due to random genetic drift, and that dairying arose in those regions with a significant number of individuals already possessing the C/T -13910 mutation. Indeed, some analyses suggest that most of the diversity at LCT originated relatively early, possibly even before the advent of farming. The archaeological evidence, however, contradicts this hypothesis. Perhaps one of the most interesting studies on lactase persistence’s origins is by Baja-Pereira and colleagues that compares the diversity of milk protein genes in domestic cattle in Europe, a proxy for the genetic history of dairy cows, with the frequency of lactase persistence in Europeans. The correlation is striking, although perhaps not surprising. Both maps show a heavy concentration in north-central Europe and southern Scandinavia, which declines to the south and east, suggesting that lactase persistence and cattle farming share a tightly linked common history probably originating in northern Europe. It is a remarkable example of two species evolving in tandem to cope with a constructed niche.

Lactase persistence is not as beneficial for survival in modern western society as it was in early dairying societies, because the great diversity of foods that are available to us. Lactase supplements also make it easy to live healthy lives even without this valuable food source. Being lactose intolerant is little more than an inconvenience in contrast to earlier dairying societies in which the consequences of lactase intolerance were probably much more severe. Those of us who cannot process dairy are generally just as likely to survive and to reproduce as those who can. Thus lactase persistence is currently subject to random, rather than directional, evolution. But if you are one of the lucky mutants that has held onto your ability to produce lactase, then remember, next time you open the fridge for a glass of milk or go out with friends for ice cream, that you are part of a millennia-old tradition of milk drinkers, gifted with a lucky mutation inherited from an early cattle-rearing ancestor.
David H. Newman M.D. is an emergency room physician and Director of Clinical Research Medicine in the Department of Emergency Medicine at St. Luke’s-Roosevelt Hospital. He served as a major in the army reserve in Iraq, where he received an Army Commendation Medal. He also teaches a class at Columbia University for those interested in clinical research called, Introduction to Clinical Research in Emergency Medicine and runs the Academic Associates research assistant program. During college, Dr. Newman studied philosophy but stumbled into medicine when he worked with EMS to pay for his education. He decided to take an EMT class after feeling angry with himself for being unable to help someone in a medical emergency. Although he says he “wasn’t picky about his philosophy,” he focused on anthropology and linguistics. Newman says that a background in philosophy “helps anyone do anything.” He feels that learning how to think and reason is especially important, when considering the present communication between science and society. Newman participated in a lot of different activities during school, including varsity baseball. He said he balanced all of his activities poorly but said, “I think I fit everything because I loved doing it and I would find a way.” He continued his studies in philosophy during graduate school but decided to follow a career in medicine since he “dug” working as a paramedic. After completing the required science classes, he went to medical school in Albany and completed a residency at University of Pittsburgh. Dr. Newman also completed a fellowship in clinical research and emergency and resuscitation research at University of Pittsburgh. As a physician, he has worked extremely hard, having taken 1 sick day in 9 years.

Influenza makes those affected feel exceptionally tired. Individuals develop a severe cough, body aches, chills, and a high fever. Influenza is a common respiratory illness caused by RNA viruses and can be fatal if untreated. Typically referred to as just “the flu,” influenza affects birds and mammals and targets the respiratory tract, composed of the nose, throat, and lungs. In children, influenza symptoms may also include nausea, vomiting, and diarrhea. Those symptoms are less common in adults.

Even though he sees patients complaining of flu-like symptoms frequently, Dr. Newman did not enter emergency medicine for the cold and the flu patients. Like many who enter the emergency field from EMS, he was attracted to the resuscitation aspect. He did feel that the minor illnesses such as “flu-like illness” became more significant to him as he advanced in his career. He said, “Talking to humans is dif-
different strains: H1N1, responsible for regular seasonal flu epidemics, whereas the presence of the novel strain can be thought of as just a variant of the regular flu strain, with the term "pandemic" attached to the novel strain responsible for the 2009 pandemic.

Despite the media hype lavished on the H1N1 pandemic, Newman notes that everyone is afraid that they have swine flu. He believes that this is an understandable reaction given that the press leads everyone to believe that anyone who is sick with a cold or cough will probably die and should rush a medical professional. The media does this because "all the news stations have to make a profit first." Their revenue comes from advertisers who pay to run ads on their news program. Advertisers will only sponsor a program if there's good viewership, which depends on an unseen audience that can scare people into "watching." For example, if a news teaser says something like "strollers that kill," it's possible that they stay home unless they are in dire need of a medical professional, in the case of extreme illness. The drug companies advertise Tamiflu and Relenza as being capable of saving the lives of those who take it, contrary to the evidence. According to Newman, of the studies that have been done on Tamiflu there was no difference found between the amount of people who died in the Tamiflu group and the placebo group. Based on this information, Newman believes that it's wrong to lead patients with the idea that a pill will prevent them from dying or getting critically ill from the flu.

In response to President Obama making H1N1 a national emergency, Newman says, "public health messages are designed to have an effect on citizens. They're not always designed to inform citizens of what is truthful and honest." The White House wants the public to get vaccinated just in case this flu outbreak turns out to be enormously deadly and catastrophic. Their agenda is to prevent a possible disaster, not to inform the public of the truth.

Seasonal flu, H1N1 (swine) flu, and avian flu are all members of the influenza A genus. However, despite shared common symptoms, differences among the three influenza A subtypes exist in their genetic makeup as well as behavior. Whereas human flu viruses are generally not fatal, the H1N1 subtype of the avian flu is much more lethal, killing over fifty percent of those infected. The novel H1N1 strain responsible for the 2009 pandemic elicits similar symptoms and is transmitted in much the same way as the H1N1 strain that causes seasonal flu. Despite the media hype lavished on the H1N1 pandemic, the novel strain can be thought of as just a variant of the regular flu strain, with the term "pandemic" attached to signify not the virus' lethality but rather the virus' spread.

According to Newman, populations with chronic illness are probably more risk for morbidity and mortality. For example, a recent CDC report Newman read of the 36 children who died of H1N1 in May and August, 22 of them suffered from chronic illness. However, many of the CDC at risk recommendations, such as the elderly, are "not based on data." He has personally seen cases of swine flu at St. Luke's and Roosevelt, but it's less prevalent than severe pneumonia. "The scale that we have made ourselves scared of this is a little bit silly when you compare it to the general illnesses that we see on a daily basis and have proclivity to do real harm," Newman comments.

A casual handshake, rubbing of the eye, or simply being in the presence of someone infected with influenza are some ways of contracting the illness. Once inside the body, the virus initiates its attack by first binding its surface glycocopyrons to receptor proteins on its host cells, typically those of the throat, nose, and lungs, entering the cell, and replicating its genetic information before departing the host cell. Symptoms are manifest, on average, one to two days after transmission of the virus.

Newman's recommendations for college students, include washing hands. Since there's not a lot of evidence that the H1N1 vaccine at this time will save lives, getting the vaccine should be an individual decision. Stay home, if you get sick unless you begin to have severe symptoms such as difficulty breathing. People should stay away from hospitals unless absolutely necessary because 'there's more H1N1 inside a hospital than outside,' you have the potential to make the sick people in the hospital even sicker, and more sick people die due to reduced resources. According to Newman, "one thing that we've proven in the world of emergency medicine is that when we crowd emergency departments people die." It is because the hospital spends time and resources treating minor illnesses that can be treated elsewhere while the patients with major illnesses don't get the attention they need.
The science behind naps

Helena (Hao) Wu

With schoolwork, jobs, activities, and noisy roommates keeping you from a “normal” eight-hour sleep schedule, many college students take naps during the day to keep up. Before getting some shut-eye during lectures or snoozing for a few minutes in Butler, consider learning the science behind sleep to optimize your nap efficiency.

Do you wonder why some naps leave you refreshed and energized, and others leave you even more exhausted than before? Everyone believes in a different napping method and mastering the art of napping first requires an understanding of the sleep cycle.

College students lead busy lives that leave little time for sleep. A well-timed nap can not only refresh you, but also strengthen your memory. A recent study shows that naps contribute to memory enhancement and improved performance during the day. Some employers believe naps to be so effective in increasing productivity that they have even built nap facilities so that workers can catch a quick snooze during the workday. A corporate firm in Dallas, Kaye/Bassman, even installed a relaxation room, complete with massage chairs, headphones, and light dimmers, for their employees. By manipulating the sleep cycle, people can rejuvenate their minds during short periods of sleep.

The body is in a deeper resting state during the REM cycle. The NREM-REM cycles alternate throughout the night, with the REM portion lengthening and the NREM portion decreasing in time as morning approaches.

The average person takes around an hour and ten minutes to transition from NREM sleep to REM sleep. However, after physical exercise or sleep deprivation, the transition to REM sleep is quicker and the amount of REM sleep increases. A major difference between the two cycles is that NREM sleep rejuvenates the body, while REM sleep repairs the brain, increasing cerebral protein synthesis and reprogramming the brain so that information learned throughout the day can be better consolidated and recalled later on.

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The body alternates between the two cycles, the timing of naps is crucial to achieving the maximum alertness upon waking up. Waking up before entering the deep REM sleep is recommended because once the body enters the REM cycle, getting up during the cycle could result in grogginess and fatigue. Although the length of NREM sleep preceding REM sleep varies from person to person, the nap length guideline is around thirty to fifty minutes. The time of the day in which the nap takes place also affects the efficiency of the nap. Sleeping too late can interfere with the circadian rhythm, your natural 24-hour cycle dictated by light and darkness. A region of the brain known as the hypothalamus and receptors in the retina of the eye regulate the circadian cycle and establish sleep patterns. By napping at unusual hours, you are, in a sense, toying with your biological clock. That’s why it is wise to avoid naps after three in the afternoon.

The more we learn about how the sleep cycle works, the more people try to find ways to use it to their advantage. For example, professionals such as military piloting and long distance boat racing demand numerous hours of alertness, with few hours of sleep. NASA researchers have found that a 26-minute nap increased pilots’ performance by 34 percent. Thus, these professionals often adopt a “polysphastic sleep” schedule, sleeping multiple times during the day for short durations in order to stay mentally alert. One such sleep schedule is called the “Uberman.” The Uberman schedule consists of six twenty-minute naps: a total of only two hours of sleep each day. These short naps allow the body to immediately enter REM, resting the mind. The strict Uberman sleep schedule requires discipline and several weeks of adjusting to the intense sleep deprivation.

Recently, bloggers have shared their experiences of incorporating the Uberman sleep schedule into their daily lives. They report that it is difficult to transition to Uberman sleep and even harder to maintain the schedule in the long-term. After all, can the extra several hours awake outweigh chronic sleep deprivation?
Upon birth, we each bring certain information to the table; whether it is blithely assigned by genetic mutations, or ostensibly flawless, this information in the form of genes influences our personalities, psychological development, and overall growth. Genes use the human body as a vehicle to transport and carry themselves from generation to generation, and as a vector within which to evolve. While genes provide the basic layout for the brain, our psychological development is then refined by experience and societal expectations.

When individuals enter the world, their personality, intelligence, and ultimately what is expected of them could be affected by where they are in the birth order line. Since the late 19th century, scientists have debated whether or not birth order influences intelligence and psychological development. They argue that birth order effects are either natural consequences of favoring firstborns because they are most biologically apt to continue the species, or are natural consequences of cultural expectations shaping the brain. In actuality, these debates reveal that birth order is neither strictly a cultural, nor biological, phenomenon, but rather a mixture of both.

From a biological standpoint, birth order effects can be reduced to the genetic influence on psychological development and the Darwinian theory that parents subconsciously assess the “reproductive value” of their offspring. Darwin suggests that parents favor the offspring most capable of reproducing (older ones, firstborns) because they can further the species and quickly pass on genetic information. Although parents may not know whether or not their firstborn possesses a “good” representation of their genome, it seems that instinctually feel the necessity to assure that their genes continue through the human species.

While genes shape the brain and may influence humans to favor one offspring over another, each child within the human body does not necessarily abide only by the ubiquitous genetic code. Like a stem cell, the human being as a whole is pluripotent, engendered with some predisposed characteristics, yet impressionable to surrounding influences and expectations. “Genes influence your intelligence and willingness to take risks,” while “social dynamics unconsciously shape your choices.” The most prevalent argument regarding birth order and intelligence is that firstborns tend to be more intelligent because resources are disproportionately devoted to them; firstborns have the opportunity to relish their parent’s undivided attention and adoration before other siblings arrive (if they even do). They have adult influences early in life and without other children close in age in their family, they must adapt and interact with their parents and other adults. Like a stem cell, differentiates in order to fit in with its environment either among heart cells, skin cells, or brain cells, etc., a child must adapt to fit in its environment.

Scientists use standardized test scores to show that a disparity in “intelligence levels” amongst siblings is indeed a birth order effect. In a Norwegian study on 241,330 men who took IQ tests before being drafted into the army during the mid 1960s and 1970s, firstborns had an average 3 IQ point lead over the next eldest child. These 3 points may seem minor, but even a 2.3 IQ point advantage can equate to a 15 point advantage in SAT scores. Such a lead could “make an even bigger difference when you’re an Ivy League applicant with a 690 verbal score going head to head against someone with a 705.”

Since World War I, researchers have been seduced by the standardized test, marveling at its simplistic design and the concept that one’s level of intelligence could simply be assigned a number. However, standardized test scores could rather reflect what type of learner you are. For instance, a “sequential” or analytic learner who tends to learn at a rate determined by the clock and follow linear reasoning procedures, may do better on a standardized exam than the contrary “global” learner. Global learners often have difficulty understanding the most rudimentary parts of a problem and tend to make intuitive jumps, failing to comprehend the progress toward a solution. Therefore, they tend to do more poorly on standardized tests where a systematic approach is often more useful. Perhaps firstborns tend to do better on standardized tests because their learning styles are different and more compatible with the standardized test format and questions.

This emphasis on using standardized tests to classify individuals according to intelligence reflects our standardized society, where most colleges and graduate schools require entrance exams to stratify applicants. Because society and the government have favored one type of learner over the other, and by extension, one child in the birth order over the rest. Since firstborns tend to score higher on standardized exams and are supposed to be “smarter,” the erroneous societal expectations explained above reinforce the idea that culture affects birth. Society seems to render the firstborn more “intelligent” by expectation, and later-borns less intelligent.

While personality is in part genetically defined, it also appears to be influenced by cultural expectations along the birth order line. Frank Sulloway, a birth-order analyst, reveals the effects of birth-order by using the “Big Five Personality Dimensions” to classify siblings according to Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Firstborns tend to score higher on Extraversion than later-borns, since they display dominance and assertiveness as leader of the brood. They also tend to score higher on conscientiousness because they have conformed to their parents’ values and respect authority more, given their closeness with their parents. Perhaps because firstborns are culturally expected to be the “leader of the brood,” they might feel that need to conform and fill this role.

Contrarily, later-borns will score higher on Openness, or honesty, be...
cause they cannot identify as much with their parents. Openness is also associated with rebellion and recklessness because unlike firstborns, later-borns can take needless risks, seeing as they are not favored for survival and repro-
duction.7 Later-borns are also both outgoing and antago-
nistic, tending to counter authority. Richard Zweigenhaft, a
Guilford College psychology professor, conducted a study of
picketers at labor rights meetings. When the events got
out of hand, he interviewed the people rounded up by the
police, and found that more and more of them were later-
borns.3 Could this antagonism and rebellion result from
the constant need to steal the spotlight and step out
of the inescapable shadow of the oldest sibling? Maybe so,
or it could result from the later-borns giving in to cultural
influence to defy the firstborn, and fully the disobedient
expectation of the later-born.

These personality differences also appear to affect what
jobs firstborns and later-borns generally have. For example, in
a survey of the heads of Fortune 500 companies, 23% were
middle-borns, and 23% were last-borns. Firstborns are disproportionately found among surgeons and M.B.A.s. There are
an excessive number of firstborns in Congress as well, and
the majority of U.S. presidents were firstborns. It has been suggested that firstborns overpopulate such jobs because
it is often in the nature of the position to be conscientious and
commanding. In these positions, firstborns often end up be-
ing more successful and making more money (1% more than
other siblings).3 Sandra Black, a professor at UCLA, found that firstborn CEOs are more successful because they make incremental and sequential
alterations to companies and try to maximize profits, while
later-born CEOs tend to throw out whole operations and
begin projects anew. Since later-borns are often more comi-
cial, and free-thinking, when they choose more appropriate
fields (according to the Big Five), you could end up with the
likes of Voltaire, Mark Twain, and Jonathan Swift, three of
the greatest satirists. You could even end up with Stephen
Colbert, the youngest of 11 children.3

Nonetheless, in his novel, Outliers, Malcolm Gladwell
suggests that if we want to understand how people are
so successful, we should spend more time “looking around
them,” remarking upon such things as their birthplace and
family. New York Times writer, David Brooks, adds to
Gladwell’s thesis stating, “Exceptionally successful people
are not lone pioneers who created their own success. They
are the lucky beneficiaries of social arrangements.”1 While
Gladwell may be right in that nurture is an essential part
in cognitive development, you cannot fail to recognize that
“nature” in the sense of biological factors also influences
intelligence, personality, and success. In the end, the bio-
logical, evolutionary argument is culturally and “societally
drawn from”, the cultural factors, the biological factors
may not have the same effect on intelligence, personality,
and birth order. In the face of this hefty birth order argu-
ment, I can only hope you don’t run off to your parents
demanding to know how they could have paid more atten-
tion to their other siblings.3

The surplus of firstborns in such demanding positions
clearly supports the hypothesis that firstborns are essen-
tially influenced by society to be leaders of the brood, and
be compatible for such jobs, while later-borns are influenced
to defy authority while still conforming to the cultural ex-
pectations designed by them. With the Gautier children driving
the economy and doctors providing for the survival of the
population, is any surprise that firstborns are favored? Af-
ter all, doctors, presidents, and 90% of CEOs were college
graduates, who perhaps revered in all of the resources de-
1. History and first examples

The Last 200 years mathematics has seen a return of geo-
metric techniques at large. For most people, “geometry” is
a word reminiscient of theorems about triangles and circles
dating back to ancient Greece. However, there have been nu-
erous developments in the subject dating between ancient
times and the 1800s; yet what makes the latter period so
interesting is both historically and mathematically, is the sys-
tematic and rigorous development of topology. Many de-
scribe topology as the study of “rubber geometry," or more
informally, of objects which allow deformation. We will at-
tempt to recover the logical sequence of constructions which
lead to the modern definition of a topological space by Ka-
zierz Kuratowski dating back to 1922.

Our story starts in the early days of calculus, during the
17th century. Sir Isaac Newton and Gottfried Leibniz, the
two main scholars working on this new fascinating field. They
developed ideas which have nowadays become an integral part
of mathematics - derivatives, integrals, differential equations,
and many other. Despite the brilliant foresight of these great
men, from a modern point of view their work was little, if
no rigor. They talked about converging sequences, series and
taking limits without really having concrete explanations of
what these meant. However, the foundational problems had
to wait until the early 19th century to be resolved. Augustin-
Louis Cauchy was the first to formulate our modern “episolon-
delta” definition of continuity.

Let us consider a map $f : \mathbb{R} \to \mathbb{R}$, or in other words a func-
tion from the real number to the real number. In fanciful
mathematical language, this is the good old graph we plot in
the $x$-$y$ plane. In this context, we can vaguely formulate con-
tinuity as the ability to draw the graph with a pencil without
having to lift it from the plane. This concept is illustrated in
figure 1.

This is an extremely naive definition. There are many ques-
tions which cannot be resolved. These are functions which do
not jump at isolated points as the one above, but infinitely
ten in a dense manner. These cannot be graphed in such
an idyllic fashion, yet they allow some continuous points.
Even more, the mere mention of a “penick” makes the flaw
extreme. Cauchy’s “episolon-delta” definition fixes these
issues. According to the definition, the function $f$ is continuous at
some point $x$ if $|f(x) - f(y)| < \varepsilon$ for all $\delta > 0$.

The symbols - refers to the universal and existential quan-
tifiers, which are read “for all” and “there exists” respectively.
In English, the above expression says for all $\varepsilon > 0$ there
exists some $\delta > 0$ such that $y < \delta < x$.

The symbols $\varepsilon$, $\delta$ - refer to the universal and existential quan-
tifiers, which are read “for all” and “there exists” respectively.
In English, the above expression says for all $\varepsilon > 0$ there
exists some $\delta > 0$ such that $y < \delta < x$.

"Current spaceship design would be deadly if applied to space
habitation."
3. Topological spaces

The final goal of this article is to understand the concept of continuity in a more general setting. In our definition using Euclidean distances, we pass numerous objects of interest to geometry, analysis, and other areas of mathematics. They also cover much more than we could have initially expected. For example, under certain conditions the set of continuous functions between two metric spaces can itself be turned into a metric space, which is the most basic example of functional analysis studies.

T (X,T) which satisfies the above three properties is called a topological space. We often omit the collection of opens T and refer to a topological space simply by its set of points, in our case X. Before continuing, let us take a closed look at the definition above. Part (a) is very simple, but (b) and (c) could be very confusing. In particular, it is not clear why we restricted intersections to be finite, yet allowed unions to be infinite. The formal answer is this mimics the familiar case of metric spaces and the definition of openness there. It is easy to check that the union of an arbitrary collection of open sets in a metric space is again open, and similarly, that any finite intersection of opens is also open. The finiteness condition is imposed since it is possible to construct an infinite collection of open subsets in a metric space whose intersection is not open. If for any integer n ≥ 1 we let Un denote the interval (−1/n, 1/n), then the set X \ {0} is definitively not open, which explains the ratio...

Let X be an arbitrary set. We will consider a collection of subsets T of X and declare these open. This is a very drastic approach to defining openness. By ourselves of the metric structure, we are left with nothing else but to "define away" the problem. If the opens in T are to behave analogously to the case of metric spaces, we need to impose several conditions: (a) both the empty set and the entire space are open. (X,T) (b) finite intersections of opens are open (if U1,...,Un are open, then T \ {U1 \cup...\cup Un} \ T). (c) arbitrary unions of opens are open (if U \ T for all A, then S(U) \ T). A map (X,T) which satisfies the above three properties is called a topological space. We often omit the collection of opens T and refer to a topological space simply by its set of points, in our case X. Before continuing, let us take a closed look at the definition above. Part (a) is very simple, but (b) and (c) could be very confusing. In particular, it is not clear why we restricted intersections to be finite, yet allowed unions to be infinite. The formal answer is this mimics the familiar case of metric spaces and the definition of openness there. It is easy to check that the union of an arbitrary collection of open sets in a metric space is again open, and similarly, that any finite intersection of opens is also open. The finiteness condition is imposed since it is possible to construct an infinite collection of open subsets in a metric space whose intersection is not open. If for any integer n ≥ 1 we let Un denote the interval (−1/n, 1/n), then the set X \ {0} is definitively not open, which explains the ratio...

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