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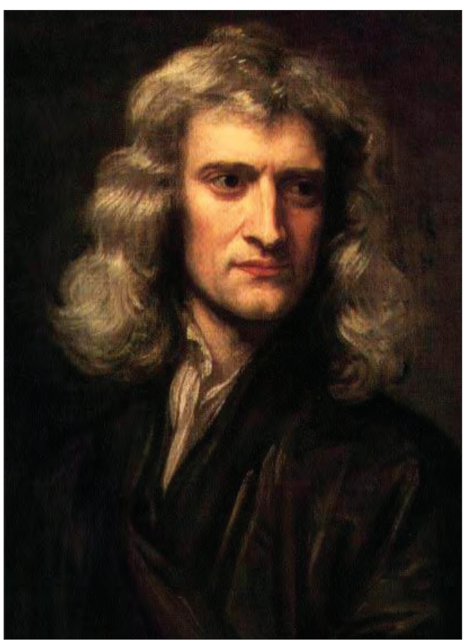
Physics

Time and the Laws of Nature

Lee Smolin, Professor of Physics at the University of Waterloo, spoke at Dartmouth this fall on the concept of time and the evolution of physical laws. Smolin, a theoretical physicist, asserted that scientific laws must have changed over time in order to effectively describe the apparent nature of the universe.

Together with his colleague Roberto Unger, Smolin attempted to address the definition of a scientific law. “Must laws be timeless or can laws change over time?” He described the concept of the Newtonian paradigm, which asserts that the entire physical world is composed of systems with states that are affected by dynamic laws. In Newtonian paradigm, a theory must cover all the possible states a system that can be found in and account for how these states change over time.

Smolin believes that the application of a subsystem of Newtonian paradigm theories and laws to the universe is incorrect. According to Smolin, the application of subsystem laws to the universe is a cosmological fallacy that results in gaps and irrationalities called cosmological dilemmas. Smolin states that scientific laws, as the most fundamental descriptions of nature, must be applicable to the whole universe and not just to special cases.



Isaac Newton’s physical laws may form the basis of modern understanding of physics, but they overlook the relevance of time to scientific law.

Two popular axioms in modern physics that Smolin and Unger challenge are that time is an illusion and that our universe is just one of many universes. The two believe in “monoworldism,” a theory that purports that there is only one universe. They reject the idea that time is an illusion and believe that the reality of time means that everything that is real exists in the present. They emphasize the importance of the present and argue against the irrelevance of time to physical law.

Biology

The Origin of Life

In 1952, Miller and Urey synthesized amino acids from inorganic precursors by simulating early Earth conditions. This created a new field called astrobiology, the study of how life arose in a seemingly inhabitable universe. The field and its development was the topic of a lecture titled “The Origin of Life” given by Marcelo Gleiser, Dartmouth Professor of Physics and Astronomy, at the E.E. Just Science Symposium this fall.

Hydrogen and helium were the only elements that existed during the universe’s early history. Gleiser explained that all other elements, including oxygen, silicon, iron, and other key components of the Earth were formed by nuclear fusion in the center of stars. Supernovae from dying stars injected these new elements into space. Gravity then clumped the resulting stardust into planets. Earth’s formation and development in particular were characterized by bombardment from comets and radiation, which injected additional elements unto the planet. With these ingredients, elements formed simple but crucial molecules like methane and ammonia. Spherical drops of lipids akin to the membranes of modern cells shielded chemical reactions from the outside environment. These conditions eventually allowed for the development of RNA. Early RNA was self-replicating and over time eveolved into DNA-based life.

Around 2.5 billion years ago, early autotrophic cyanobacteria started oxygenating Earth’s carbon dioxide-rich atmosphere. This new environment was conducive to eukaryotic and multicellular life, resulting in more specialized organisms over the ages. However, Gleiser stresses that life does not strive to evolve into more “advanced” or “cognitive” forms. One cannot predict that natural selection will “create an elephant out of a bacterium,” Gleiser says.

The chances of life developing on one of the planets surrounding the billions of stars in billions of galaxies are astronomically high. However, most extra-terrestrial life is probably simple and underground. Although only a tiny fraction of all life is intelligent, the degrees of sophistication even within that tiny fraction are huge. Hence, Gleiser suggests: “We likely are not the most advanced beings in the universe—for all we know, humans are meant to liven up some alien civilization’s space ‘Petri dish.’”

Anthropology

The Grandmother Hypothesis: An Explanation for Human Development

Kirsten Hawkes, Professor of Anthropology at the University of Utah, recently presented her research supporting the Grandmother Hypothesis at Dartmouth’s E.E. Just Symposium. The Grandmother Hypothesis states that the longevity of human females during post-reproduction years allows them to help raise their grandchildren, thereby increasing the chance that grandchildren will propagate this post-reproduction longevity trait. The grandmother hypothesis is an exception to conventional natural selection theory which considers selection irrelevant after reproduction.

Hawkes explains that human mothers

Image courtesy of NASA (accessed 25 Oct. 2012)

An image of Andromeda, Messier 31, the galaxy cluster which contains our Milky Way. The probability that other life forms exist in Andromeda are high, according to Professor Glesier

differ from chimpanzee mothers in the manner they raise their children. While chimpanzees and other primates tend to raise their offspring alone, human mothers receive help from others like members of their the immediate family. This allows human mothers to have more children and with greater frequency. A chimpanzee mother has to wait until its offspring is totally independent, which can take a total of five to six years. In contrast, a human mother can reproduce before her current child can fend for itself.

Hawkes asserts that, over time, humans have evolved to be more social than other primates because human mothers have to pay attention to several children at once. This unique childrearing environment may partially explain why humans have an innate desire to be connected to each other .

Mathematics

Cracking Down on Crime with Applied Mathematics

Andrea Bertozzi, a Professor of Mathematics at the University of California, Los Angeles, presented her research on the mathematics of crime at Dartmouth College this fall. Bertozzi's research is on the development of algorithmic predictive models of crime patterns in urban regions,

Beginning her work with the Los Angeles Police Department (LAPD), Bertozzi used quantitative models to predict where crimes were most likely to occur in the city. Informed by Bertozzi's models, LAPD patrols now receive alerts before each shift on predicted hotspots. According to Bertozzi, targeted patrols like these contributed to decreases in crime rates by up to 27 percent.

Bertozzi's models began with routine activity theory. Routine activity theory states that crimes are more likely to occur where more offenders encounter potential targets. By mapping potential offenders and targets on 2-D grids, Bertozzi creates models that simulate crime patterns. Factors used to estimate the likeliness of a crime include the attractiveness of a location to crime and the security of potential targets.

Bertozzi and her team also use census data, crime density estimations, and high-resolution image processing to inform their models. By considering the expected decrease in attractiveness of a target over time and informing recent crimes into the models, Bertozzi's models strive to hone in on localized criminal hotspots in real time. In an added layer of complexity, Bertozzi's models also predict how effective police forces will likely be able to respond to a crime.

Bertozzi's most recent project has been mapping gang networks in Los Angeles. She attempts to model gang boundaries by simulating violence and retaliations. Using these models, Bertozzi has presented important evidence on unsolved gang crimes and suspet crimes to the police.

Although Bertozzi and her team only started working with the LAPD seven years ago, large advances have already been made in using mathematics to fight crime. As crime continues to evolve, Bertozzi's team plans to continue to advance their models and mapping techniques.

Medicine

Cognitive-Behavioral Intervention as a Way to Treat Alcoholism

For most medical conditions, financial concerns are the biggest barrier to the effective delivery of treatment. However, other more complicated factors can make it difficult for those with substance use disorders to seek therapy. One of the greatest challenges for a substance abuser can be the act of convincing himself that he needs outside help.

Tracy Stecker, Professor of Community and Family Medicine at the Geisel School of Medicine, explored the use of cognitive-behavioral intervention (CBT) to influence the rate of treatment initiation among alcoholics in a recent paper. The results indicated that the participants who received CBT were three times more likely than those who did not to attend treatment sessions within a three-month period.

Cognitive-behavioral therapy operates under the assumption that cognitions, feelings, and behaviors all interact with one another, and therefore seeks to influence patients' outlook towards treatment by changing beliefs related to the care.

In Stecker's study, individuals were divided randomly into a control group assigned to read a pamphlet about the dangers of alcohol use, or an intervention group assigned to receive CBT.

In the control group, only 11 respondents (12%) sought medical treatment and an additional 13 attended AA meetings. In the group that had undergone CBT, 25 respondents (30%) received treatment while 17 went to AA meetings. An odds ratio of 3.14 was recorded, indicating a clear increase in treatment-seeking behavior from patients that underwent CBT. This success suggests CBT as an effective option for alcoholics who need additional encouragement in seeking therapy.

In the future, an expansion of CBT application in influencing treatment-seeking behavior could provide for a gradual dip in the number of substance abuse patients without care.