Creative Campus: Learning with Latitude
General Paper: Notes and Essay Writing

Frontiers of Science and Technology

Notes

Science, by definition, refers to the use of the scientific method, in which scientists formulate hypotheses, test them through experiments, and refine the hypotheses into ever-more-accurate predictions about real-world phenomena. Science is thus an ongoing effort by humans to understand the workings of the empirical world.

Science spans many diverse, interconnected, and overlapping fields, all of which are constantly contributing new discoveries and enabling technological advancements. Some of the frontiers in modern science include:

Renewable Energy (Applied Science)

At the turn of the century, it was projected that global energy use would grow by 2.5% yearly until 2050, driven by developing countries. Mathematically, there is only one way to balance the needs for electrical consumption and for maintaining planetary health. That is if the proportion of total energy use supplied by clean and renewable energy sources rises more quickly than that total. Experts estimate that by 2050 renewables could account for 16-30% in High Economic Growth scenarios, or up to 35-40% in Ecologically Driven scenarios.

According to Our World in Data, the world produced 17,000 TWh of renewable energy in 2017, compared to 10,000 in 1965. This upward trend is driven by not altruism but financial sense – as modern technologies mature, they become more economical and hence viable on the market. "Game-changing" breakthroughs (e.g. silicon photovoltaic solar cells and offshore wind farms) have proven pivotal in that regard. Investment in renewable energy has increased from $47 billion in 2004 to $286 billion in 2015. In 2018, 4,193 TWh of hydroelectric power, 1,270 TWh of wind power, and 585 TWh of solar power were generated. Geothermal and tidal energy are also increasingly attractive options. Installed power capacity for renewables grew by more than 200 gigawatts in 2019, the biggest increase on record.

Life on Other Planets (Astrobiology)

While Mercury and Venus are too cold to harbour life, Mars remains a destination of interest. NASA's Curiosity rover is currently scouting the planet for conditions conducive for microbial life, chief of which is the presence of liquid water. Other planetary prerequisites for life include a protective atmosphere, stable access to an energy source, and a self-sustaining geochemical cycle (like Earth's tectonic plates and carbon, nitrogen, and water cycles). Exoplanets like Kepler-62f, Kepler-186f, and Kepler-442b are possible candidates as well.

Although space travel began as a Cold War contest between two nations, private entities have recently entered the scene, including Jeff Bezos's Blue Origin, Richard Branson's Virgin Galactic and Elon Musk's SpaceX. In fact SpaceX, which was founded in 2002 to reduce space transportation costs and bring forward a possible colonisation

of Mars, has been building spacecraft for NASA and running resupply missions for the International Space Station since 2012. The involvement of private actors is likely to accelerate space exploration exponentially.

Genetic Engineering (Biogenetics)

DNA molecules can be understood as instruction manuals that encode the growth, function, and reproduction of living things and their biological components. A sequence along DNA chains is called a gene, while the complete DNA of a distinct organism is called a genome. Genetic materials spontaneously mutate with each iteration (due to mistakes like the addition or subtraction of one link in the chain), which manifest as intergenerational differences in form and function. Natural selection refers to how favourable mutations are more likely to be transmitted to the next generation. Artificial selection refers to how humans influence which mutations get passed on (e.g. farmers choosing the seeds of the healthiest plants, or hunter-gatherers domesticating the most sociable dogs). However, neither of these selective processes directly influence the genetic mutations themselves.

Genetic engineering refers to the direct manipulation of an organism's genetic material. Genes corresponding to certain observable, "overworld" traits (i.e. phenotypes) like size, skin colour, or wingspan can be copied and transferred within and across species boundaries to produce organisms with those desired traits. These tend to be motivated by industrial interests, such as improving yield and resistance to pests and pestilence. For example, insect-resistant cotton, eggplant, and maize contain a gene from the bacteria Bacillus thuringiensis. More ethical applications include regenerative technologies like stem cell transplants and the engineering of bacteria to produce human insulin for diabetics.

The latest technique is CRISPR-Cas9 gene editing, which stands for "clustered, regularly interspaced, short palindromic repeats". It is based on a system in bacteria that, like a pair of scissors, snips targeted sections of DNA from invading viruses and stores them in case of future attacks. CRISPR-Cas9 is less of a blunt weapon than using radiation to provoke genetic mutations, as its ability to target a precise area avoids triggering knock-on side-effects. Genetic editing is being used in medicine to teach immune systems to attack cancer cells, and to stop HIV virus DNA from replicating. It was also the technology used by He Jiankui to create the world's first human genetically-edited babies in November 2018.

Artificial Intelligence (Computer Science)

Artificial Intelligence (AI) refers to the capacities and functions in machines that parallel the natural intelligence displayed by higher mammals and other animals. Intelligence itself is difficult to define, so AI too is inevitably broad and fuzzy in scope. Generally, it is the property of machines that act to achieve a goal by acquiring or utilising knowledge and responding to environmental conditions. Some subfields

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include machine learning (self-improving algorithms that continually analyse feedback and eventually perform tasks the robot was never explicitly programmed to do), natural language processing (parsing and producing human language), and precision agriculture and medicine (programmes that efficiently direct the optimal types and quantities of fertiliser/drugs to target areas).

Self-driving cars and trucks are paradigmatic examples of AI, since the machine has to receive a variety of input in real time and compute what speed is safest, what route is optimal, how to respond to the surrounding vehicles etc. In July 2020, Elon Musk announced that Tesla was "very close" to achieving complete autonomy (level 5), which requires no driver input. Tesla's current, level 2 autopilot AI requires the driver to hold on to the wheel and remain ready to intervene. Self-driving startup TuSimple announced the world's first autonomous freight network in July 2020 as well, while Chinese ride-hailing firm Didi Chuxing has plans to operate a one-million-strong fleet of self-driving taxis by 2030.

AI is already being used in medicine, most prominently by radiologists to identify and analyse X-rays for malignant symptoms. Given the algorithmic (rule-based) nature of healthcare, there is much potential for AI-driven optimisation. According to Microsoft, 80% of US patients do not actually respond to the top 20 prescription drugs, and there are over 800 medicines and vaccines available for cancer treatment. Its Hanover Project aims to create an assistant that computes all available data to help doctors make the most well-informed decision for each case.

US presidential hopeful Andrew Yang campaigned in 2020 on a platform warning of economic dislocation in the wake of the "Fourth Industrial Revolution". According to Brookings Institution, 25% of American jobs (amounting to 36 million jobs in 2016) face high levels of disruption due to automation. 70% of that segment risk being replaced entirely. The service sector, once thought impervious to developments in AI, includes jobs like retail that are now equally under threat. For example, Nanyang Technological University has developed the AI for Nadine, a customer service agent currently working at AIA Singapore, who can visually identify specific clients and respond to their unique profiles. Osaka University's Erica is working as a news anchor in Japan, and Hanson Robotics' Sophia has addressed the United Nations. Other than imitating speech, service bots are acquiring "human" qualities like empathy and relatability – University of Science and Technology of China's robot Jia Jia has been called the country's most beautiful woman.

Internet of Things (Computer Science)

Devices are gaining more extensive and varied functions, as well as the ability to make executive decisions based on contextual cues. Computer-to-computer communication is removing the need for much human-to-computer interaction. The Internet of Things (IoT) refers to such systems of interconnected computing devices which transmit data to one another without requiring human input.

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A modest application of IoT technology is in the concept of the "smart home", popularised in the consumer market by Google Nest/Home. Air conditioning, lights, security systems, and electronic appliances like the oven or TV can be remotely controlled or even left to its own devices (pardon the pun), locking and unlocking doors when a sensor triggers or adjusting fan speeds according to thermostat readings. This can save electricity, or address accessibility or mobility concerns in an ageing population. A more ambitious ecosystem would be the "smart city", which features the same logic on a larger scale. Systems that can be fully automated include waste management, utilities, and transport, especially if integrated with autonomous cars: parking, navigation, safety, toll collection, and traffic control could be managed independently and "smartly" by the IoT.

Essay Questions

1. Knowledge is power. How true is this maxim in relation to science?

2. Is science a tool of oppression or empowerment?

3. *Barack Obama wrote in his book, *The Audacity of Hope*, "I believe in evolution, scientific inquiry, and global warming." Of a different mind is Donald Trump, who on 16 July 2020 conveyed the message that "science should not stand in the way" of national interests.

   To what extent should public policy be guided by scientific knowledge?