SciencePages

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Genomics

Genomics is the study of genomes and their interaction with the environment.

This edition of SciencePages will cover the basics of genomics as well as discuss its socio-economic, legal and ethical implications.

Genomics 101

Every cell of any living species contains genes. Genes are sequences of DNA that encode distinct pieces of information necessary for the survival and growth of all organisms. The entire set of genes in an organism is known as the genome. Passed from one generation to another, genes contain the essential instructions for building an organism and determine everything from our predisposition to diseases to how some bacteria can survive extreme temperatures.

DNA sequencing machines allow scientists to "read" the genes and other pieces of DNA present in any genome. Like words, whose meaning comes from the context in which they are used, a gene's function can depend on what other genes are present in the genome. Some areas of DNA that first appeared to have no function and which were labeled "junk DNA" have revealed through more recent genomic studies that they may have essential roles in many cellular processes (HTTP://WWW.NATURE.COM/ENCODE/#/THREADS).

Food Safety

Health Canada estimates there are 11 million cases of food-borne illness every year[1]. Genomic analysis can allow food inspectors to quickly track pathogens like *Listeria* or *E.coli*, relying on the genetic fingerprint of the microorganism. This could improve food safety and reduce the suffering and economic losses associated with food poisoning.[2] The same approach could also be used to ensure that the meat and fish we buy at the supermarket is accurately labeled.

1 http://www.hc-sc.gc.ca/fn-an/securit/ill-intox/index-eng.php
2 http://www.genomecanada.ca/medias/pdf/en/2012-listeria-competition-press-release.pdf

What Genomics Tells Us

Armed with this "code of life", scientists and entrepreneurs are exploiting genomic information to improve health, increase productivity in agriculture, forestry and fisheries, and help clean up the environment.

Genomic research helps scientists to:

- Discover new biomarkers, (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC534923/) or genes that are responsible for, or indicative of, certain traits or diseases.
- Discover genes that are unique to an individual or a species. These genes can be used as a "barcode" (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC534923/) to identify products in supermarkets.
- Breed plants and animals more effectively at reduced cost.

Manipulating the Genome

Genetically Modified Organisms (GMOs) can be created by cutting and pasting genes from one organism into another to obtain a desired trait.[1] Genomic sequencing has allowed scientists to better understand which genes are associated with which traits, such as resistance to drought or disease.

1 http://www.hudsonalpha.org/education/kits/gmod/gmos-made

Source: Genome Canada

Genetic screening
Source: Rochester General Health System

Health Care and Medicine

WHAT'S NOW: The use of genetic screening (http://www.cdc.gov/genomics/gtesting/index.htm) to determine an individual's predisposition to a disease illustrates the impact of genomics on health care. Genetic tests have been developed for more than 2,200 diseases, including certain types of breast cancer and cystic fibrosis.

WHAT'S NEXT: Genomic research has been instrumental in discovering how our genetic makeup affects the way we respond to drugs.

This will improve the effectiveness of treatment and improve patient care by allowing physicians to make individualized drug choices and to reduce adverse drug reactions. Researchers are looking at developing tailor-made (http://www.cihr-irsc.gc.ca/e/44699.html) drugs for individuals based on their genetic code (http://www.ornl.gov/sci/techresources/Human_Genome/medicine/pharma.shtml).

Codeine

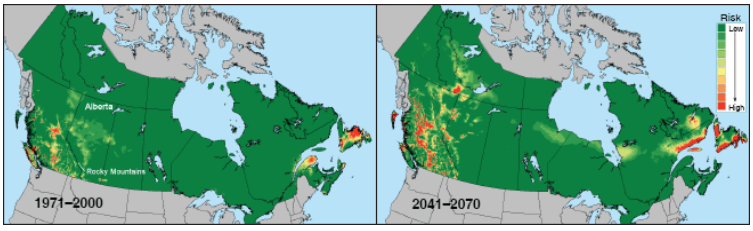
Codeine is the active ingredient in some commonly prescribed painkillers. An enzyme in the liver converts codeine to morphine, and a particular gene code for this enzyme. Depending on their genetic profile, some people metabolize the codeine faster than others – they are known as 'ultra rapid metabolizers'. Mothers with this genetic profile pass dangerous amounts of morphine through breast milk, which can harm infants. This risk was not understood fully until genomics research identified some women as 'ultra rapid metabolizers'. Health Canada and the FDA[1] subsequently issued a warning regarding the use of codeine containing products for breast feeding mothers.

1 http://www.hc-sc.gc.ca/dhp-mps/medeff/advisories-avis/prof/_2008/tylenol_codeine_hpc-cps-eng.php

Bioeconomy

Applied genomic research is helping keep Canada's traditional industries competitive and profitable. Indeed, Canada is a world leader in the application of genomics to farming. Genomics has already led to crops with improved disease and pest resistance (http://www.croplife.ca/plant-biotechnology/biotechnology-crops-in-canada), reduced pesticide use and improved nutritional value(http://ejournal.vudat.msu.edu/index.php/mmg445/article/viewFile/64/45).

WHAT'S NOW: Canola (http://www.canolacouncil.org/markets-stats/industry-overview/) was first created from rapeseed by traditional breeding techniques in the 1970s, making it safer for human consumption. Since then, researchers have found ways to further genetically modify the plant to make it resistant to some diseases and pesticides. Around 80 per cent (http://www.canolacouncil.org/oil-and-meal/canola-oil/canola-the-myths-debunked) of the country's canola crop has these additional genetic modifications.



Anticipated spread of the pine beetle in Canada
Source: Natural Resources Canada

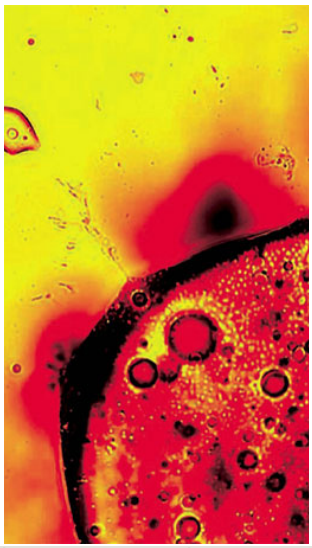
WHAT'S NEXT: The Mountain Pine Beetle (http://www.thetriaproject.ca/) has infested an area twice the size of New Brunswick across British Columbia and Alberta (http://genomealberta.ca/research/new_initiatives/pine_beetle/), posing a serious threat to the forestry industry. By mapping the genome of the beetle, the fungus it produces and the trees it targets, scientists hope to understand the interplay between these three species and use this information to control beetle spread and improve tree resistance.

Environment

Emerging applications of genomics can help address some of Canada's environmental challenges including industrial pollution.

WHAT'S NOW: Using microorganisms to "eat up" pollutants is called bioremediation (http://www.beem.utoronto.ca/research/67). Some Canadian companies are using this technology to clean up persistent organic pollutants in soils and groundwater. They are also using microorganisms to treat emissions from the pulp and paper industry. Another technology uses plants (http://phytoremediation.ca/) to remediate soils with toxic metal pollution. These plants can be genetically modified to improve their efficacy.

WHAT'S NEXT: Sequencing the genetic blueprint of microorganisms living in oil wells and knowing how they process toxins has the potential to lead to safer and more efficient oil extraction methods. Genomics research is also being done in the oil sands to help mitigate the environmental impacts of extraction in an attempt to reduce water and land use, and lower greenhouse gas emissions (http://www.genomeprairie.ca/LinkClick.aspx?fileticket=Va5uWXN2Xx0%3D&tabid=40).



Oil consuming microbes
Source: Fisheries and Oceans Canada

What should we patent? A Canadian Case Study

The Monsanto Company took Saskatchewan farmer Percy Schmeiser to court, claiming patent infringement when its brand of GM canola was found growing on his farm. Schmeiser argued that patented seeds blew into his fields from neighbouring farms. The Supreme Court of Canada ruled that Schmeiser infringed on Monsanto's patent. In this case, the Court ruled that a genetically modified cell is protected by Canadian patent law. However, the plant that is grown from that cell is not patentable.[1]

1 http://www.ielrc.org/content/a0503.pdf

Ethical, Legal & Social Implications

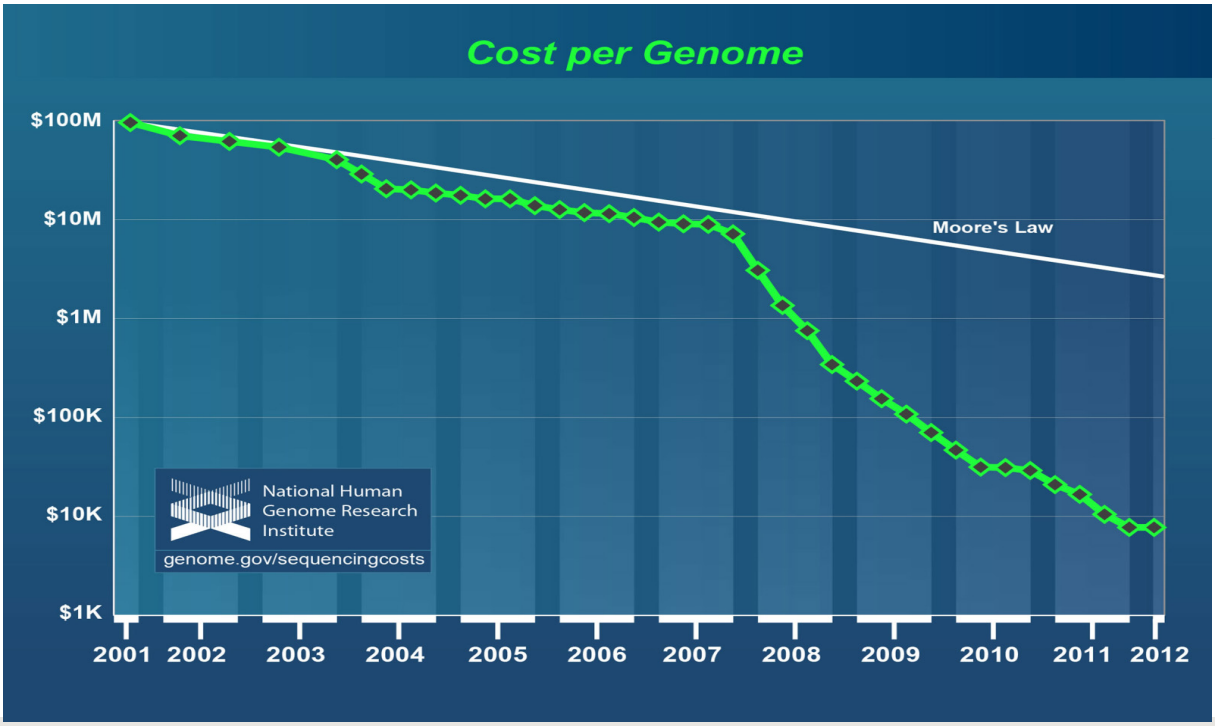
Genomic research and technologies generate enormous amounts of data. Canadian researchers are involved with, and in some cases leading, international initiatives responsible for collecting genomics data in bio-repositories(http://commonfund.nih.gov/hmp/). The creation of these central biobanks facilitates data collection and enables rapid sharing of knowledge within the research community.

However, these biobanks also raise ethical and legal issues with ownership, management, transfer and use of genetic data (http://www.genomecanada.ca/medias/pdf/en/GPS-Policy-Directions-Brief.pdf). In 2009, the OECD responded to some of these challenges by adopting a Recommendation on Human Biobanks and Genetic Research Databases (http://www.oecd.org/science/biotechnologypolicies/44054609.pdf).

Intellectual Property (IP)

If the management of data has become a growing debate, the Intellectual Property issue emerged early on, and has yet to be settled in a definitive manner. As companies and institutions began to file patents for biomarkers, it was unclear which discoveries could be considered inventions and therefore patentable.

More recent debates have centered on whether patents can also deter innovation. In some sectors, organizations are experimenting with a more creative use of IP known as "open innovation" (http://www.cpaglobal.com/download_centre/white_papers/open_innovation) where IP is used to facilitate collaboration (http://www.canadianlawyermag.com/4222/do-strong-ip-laws-stifle-innovation.html?print=1&tmpl=component)through risk sharing between potential patent holders.



The graph shows how costs associated with sequencing a genome of the size of the human genome, considerably dropped from 2001 to 2012. The reduction in the overall cost is mainly attributed to recent improvement in the technology of DNA sequencing methods.
Source: National Human Genome Research Institute

Genetic Testing and Privacy Issues

Genetic tests may reveal that an individual is predisposed to a particular disorder, yet that disorder may never develop. These types of tests create the potential for genetic discrimination (http://lawjournal.mcgill.ca/documents/Lemmens.pdf), which occurs when an individual is considered uninsurable or subject to higher insurance premiums because of genetic predispositions. While equality, personal privacy and protection from discrimination based on disability are all protected by Canadian legislation, there are currently no laws that specifically address genetic discrimination (http://www.ccgf-cceg.ca/en/about-genetic-discrimination).

Conclusion

Advances in genomics will continue to give rise to environmental, economic, as well as ethical, legal and social implications, all of which will warrant considerable attention from policymakers and the public.

Further Resources:

1. www.genomecanada.ca
2. www.nature.com/encode/#/threads
3. www.genome.gov
4. http://grdi-irdg.collaboration.gc.ca/eng/about.html
5. http://www.barcodeoflife.org/
6. http://ghr.nlm.nih.gov/handbook/basics/gene

A fully referenced version of the SciencePages is available at www.sciencepages.ca

About SciencePages

SciencePages (www.sciencepages.ca) is an initiative of the Partnership Group for Science and Engineering (www.pagse.org) in collaboration with the Science Media Centre of Canada (www.sciencemediacentre.ca).

SciencePages aims to increase discussion on topical issues that have science and engineering at their core, by summarizing the current state of knowledge and policy landscape.

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