BIO 5099: Molecular Biology for Computer Scientists (et al)

Lecture 26: Biology and Society

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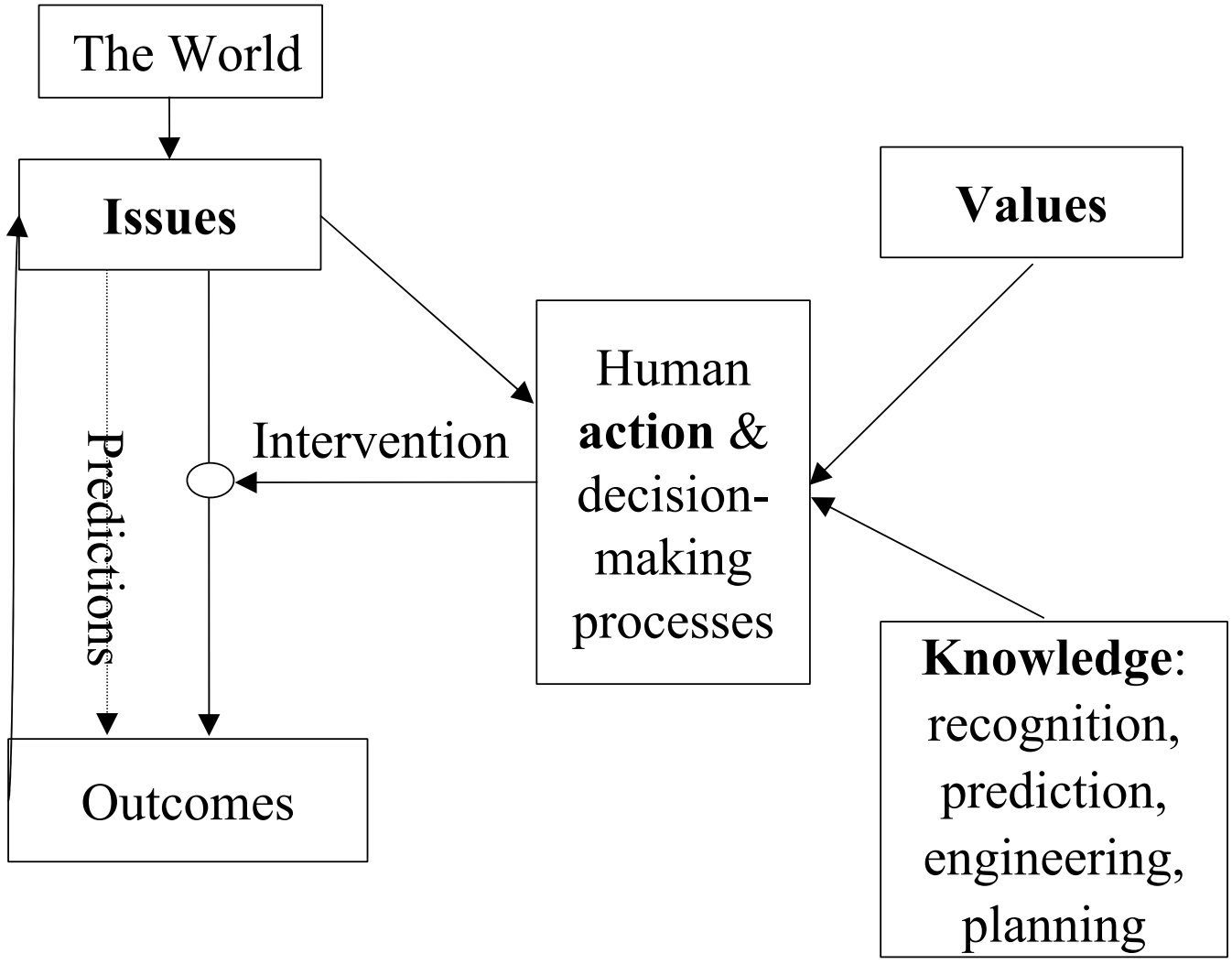
Why Social Aspects?

- Molecular biology (and biotechnology) will lead to explosive changes in the world.
  - Today, we discuss some of the ways that the topics we studied this semester will have broader social implications
- The materials in this class can help you understand (and maybe effect) these changes.
  - The **privilege** of knowledge brings with it a **responsibility** to use that knowledge for the good of the society that created it and made it possible for you to learn it.

The role of knowledge in action



This class...

- Will raise some of the issues around biology that I believe are likely to confront us.
- Is shaped by my values (particularly in the choices about what to include and not), but attempts to be reasonably value neutral.
  - Which means no prescriptions for what to do...
- May lead to conflicts based on differing values
  - So I will try to lead us away from discussions about what we should do, and towards understanding some of the challenges that may confront us.

Change is coming

- Compare the revolution in molecular biology with the advent of information technology:
  - MolBio is **half as far along** as IT
    - First stored program computer: 1946 (56 years ago)
    - First recombinant DNA: 1974 (28 years ago)
  - The social import of applications seems in many ways **more fundamental to what it is to be human**:
    - IT: Communication, Banking/Finance, Commerce(?)...
    - Biology: Food, Health/Medicine, Reproduction
  - Challenges are different:
    - IT: Infrastructure fragility, privacy invasion, alienation?
    - Bio: novel diseases, genetic pollution, germline change

Some MolBio & Society issues

- Biotechnological Problems
  - Predictive/Personalized Medicine and US Health Care
  - Genetic pollution
  - Biowarfare
- How to value life
  - Biodiversity and mass extinction
  - Lifeform patents
- What it is to be alive, and be human
  - The status of engineered organisms
  - Issues around genetic engineering and humanity
- The precautionary principle
  - How (and whether) to capture uncertainty in policymaking

Even good things present challenges

- Imagine that the promise of genomic medicine is largely fulfilled:
  - **Predictive**: tests for particular polymorphisms lead to accurate predictions of future disease.
  - **Personalized**: drugs and other therapies are prescribed on the basis genetic polymorphisms (*pharmacogenomics*)
- The current health care system is very poorly suited for taking advantage of this promise:
  - Curative, not preventive medicine (insurers won't pay to save costs in the future if people can change insurance)
  - Development costs recouped by many uses (blockbusters)

Genetic 'Pollution'

- The transmission of engineered genes to organisms other than the intended recipients
  - Many transgenic organisms will be released, through agriculture, bioremediation, accidents, etc.
  - The organisms can interbreed with wildtypes and genes may be exchanged through horizontal transmission
- Possible consequences:
  - Pests gain resistance genes (e.g. to antibiotics, herbicides or pesticides)
  - Modified organisms outcompete others, forcing extinctions
  - Unpredictable consequences of novel gene combinations

Pollution abatement?

- Gene flow in realistic situations not well understood, but currently under study:
  - Plasmid exchange and drug resistance
  - Cross-pollination among crops and surrounding plants
- Political responses:
  - Ban of all recombinant DNA research in Mexico
  - Bans of genetically modified crops in European countries
- Market responses:
  - Torts & insurance. How to detect? Who has standing? Who pays? Starlink suits from farmers *and* consumers.

Biological Warfare

- Ancient and very effective
  - From distribution of smallpox laden blankets to native Americans, to (unsolved) anthrax attack on US last fall.
  - No known uses that involved molecular biotechnology
- Molecular biotechnology allows new twists
  - Synthesis of poliovirus from inorganic materials
  - Understanding mechanisms of pathogenicity and infection may lead to engineered approaches
  - Developing immunization along with pathogen more likely
  - Equipment and skills are becoming widespread

Society and Mass Extinction

- As we discussed early in class, there is overwhelming evidence of a contemporary anthropogenic mass extinction event.
- Many issues
  - How to value biodiversity?
  - Any intrinsic value to the lost species themselves?
  - Instrumental values of lost species, e.g. as sources of valuable genes/gene products.
  - How to address biodiversity loss: endangered species laws, habitat preservation, cataloging/sampling?
  - Who pays? Debt-for-nature swaps, bioprospecting rights

Patenting Lifeforms

- Patents on life:
  - Originally denied, due to “product of nature” doctrine.
  - 1930 Plant Patent Act allowed patenting of plants that were reproduced asexually (“product of breeders”)
  - 1972 Chakrabarty applies for patent on oil-eating bacterium (plasmid), Supreme Court agrees in 1980
  - 1983 First animal patent, the Harvard Oncomouse.
  - 1999 Human chimeric patents (Rifkin & Newman)
- Patents on genes:
  - Alpha interferon was first in 1980; still lawsuits ongoing.
  - Many patents without knowledge of function!

What is 'human'

- Now, 'human' is a privileged class, and the boundaries are clear (sort of).
  - But definitions of human recently involved gender and race
- Transgenic animals may have increasingly human aspects
  - Xenotransplantation and organ farming
  - (Speculatively) suppose language depended on 10 genes that could be transfected into other primates, and the recipient organisms claimed human status?

Changes in Humans

- If gene therapy becomes safe and effective, it is likely to spread broadly
  - Dividing line between curative and performance enhancing is very hard to make, let alone enforce.
  - Differences in phenotype can rapidly become extreme
- Germline therapy is likely to follow
  - Technically very little difference from somatic therapy
  - Only way to cure developmental abnormalities
  - Hard to deny parents rights to possible cures for children
- Consequences could be dramatic; speciation?

Already identified challenges

- Human Genome Project included 3-5% setaside for related “ethical, legal, and social issues” (ELSI) research.
  - World's largest ever bioethics project
- Identified 9 areas of “Societal concern arising from the new genetics”
  - We will look at each very briefly
  - More in-depth coverage at http://www.ornl.gov/hgmis/elsi/elsi.html

ELSI issues (1-3)

- Fairness in the use of genetic information by insurers, employers, courts, schools, adoption agencies, and the military, among others.
  - Who should have access to personal genetic information, and how will it be used?
- Privacy and confidentiality of genetic information
  - Who owns and controls genetic information?
- Psychological impact and stigmatization due to an individual's genetic differences.
  - How does personal genetic information affect an individual and society's perceptions of that individual?
  - How does genomic information affect members of minority communities?

ELSI Issues (4)

- Reproductive issues including adequate informed consent for complex and potentially controversial procedures, use of genetic information in reproductive decision making, and reproductive rights.
  - Do healthcare personnel properly counsel parents about the risks and limitations of genetic technology?
  - How reliable and useful is fetal genetic testing?
  - What are the larger societal issues raised by new reproductive technologies?

ELSI Issues (5)

- Clinical issues including the education of doctors and other health service providers, patients, and the general public in genetic capabilities, scientific limitations, and social risks; and implementation of standards and quality-control measures in testing procedures.
  - How will genetic tests be evaluated and regulated for accuracy, reliability, and utility? (Currently, there is little federal regulation.)
  - How do we prepare healthcare professionals for the new genetics?
  - How do we prepare the public to make informed choices?
  - How do we as a society balance current scientific limitations and social risk with long-term benefits?

ELSI Issues (6)

- Uncertainties associated with gene tests for susceptibilities and complex conditions (e.g., heart disease) linked to multiple genes and gene-environment interactions.
  - Should testing be performed when no treatment is available?
  - Should parents have the right to have their minor children tested for adult-onset diseases?
  - Are genetic tests reliable and interpretable by the medical community?

ELSI Issues (7-8)

- Conceptual and philosophical implications regarding human responsibility, free will vs genetic determinism, and concepts of health and disease.
  - Do people's genes make them behave in a particular way?
  - Can people always control their behavior?
  - What is considered acceptable diversity?
  - Where is the line between medical treatment and enhancement?
- Health and environmental issues concerning genetically modified foods (GM) and microbes.
  - Are GM foods and other products safe to humans and the environment?
  - How will these technologies affect developing nations' dependence on the West?

ELSI Issues (9)

- Commercialization of products including property rights (patents, copyrights, and trade secrets) and accessibility of data and materials.
  - Who owns genes and other pieces of DNA?
  - Will patenting DNA sequences limit their accessibility and development into useful products

The Precautionary Principle

- If there are reasonable scientific grounds for believing that a new process or product may not be safe, it should not be introduced until there is convincing evidence regarding its risks and benefits.
- Highly controversial (mostly US vs. Europe)
  - US: Can never *prove* safety; hypothetical risks are endless; innovation is an important value in itself
  - Europe: Easier to prevent a problem than to remediate; some potential problems cannot be remediated, only prevented.

Some concluding comments

- Life is extraordinarily rich and beautiful, all the way down to its molecular mechanisms
- Although life has been an object of human study for thousands of years, recent access to molecular phenomena have yielded profound insights into many of life's mysteries.
  - And still so much remains mysterious...
- We are on the threshold of tremendous change in the living (and human) world
  - Better knowledge of all aspects of life will be of great value