

Introduction to biotechnology



Biotechnology and What Does It Mean to You?

- **Biotechnology** – using living organisms, or the products of living organisms, for human benefit to make a product or solve a problem
- Historical Examples
 - Fermentation
 - Selective breeding
 - Use of antibiotics
 - Synthesis of biopharmaceuticals

Biotechnology and What Does It Mean to You?

- **Example of Biotechnology – Selective Breeding**



Normal zebrafish



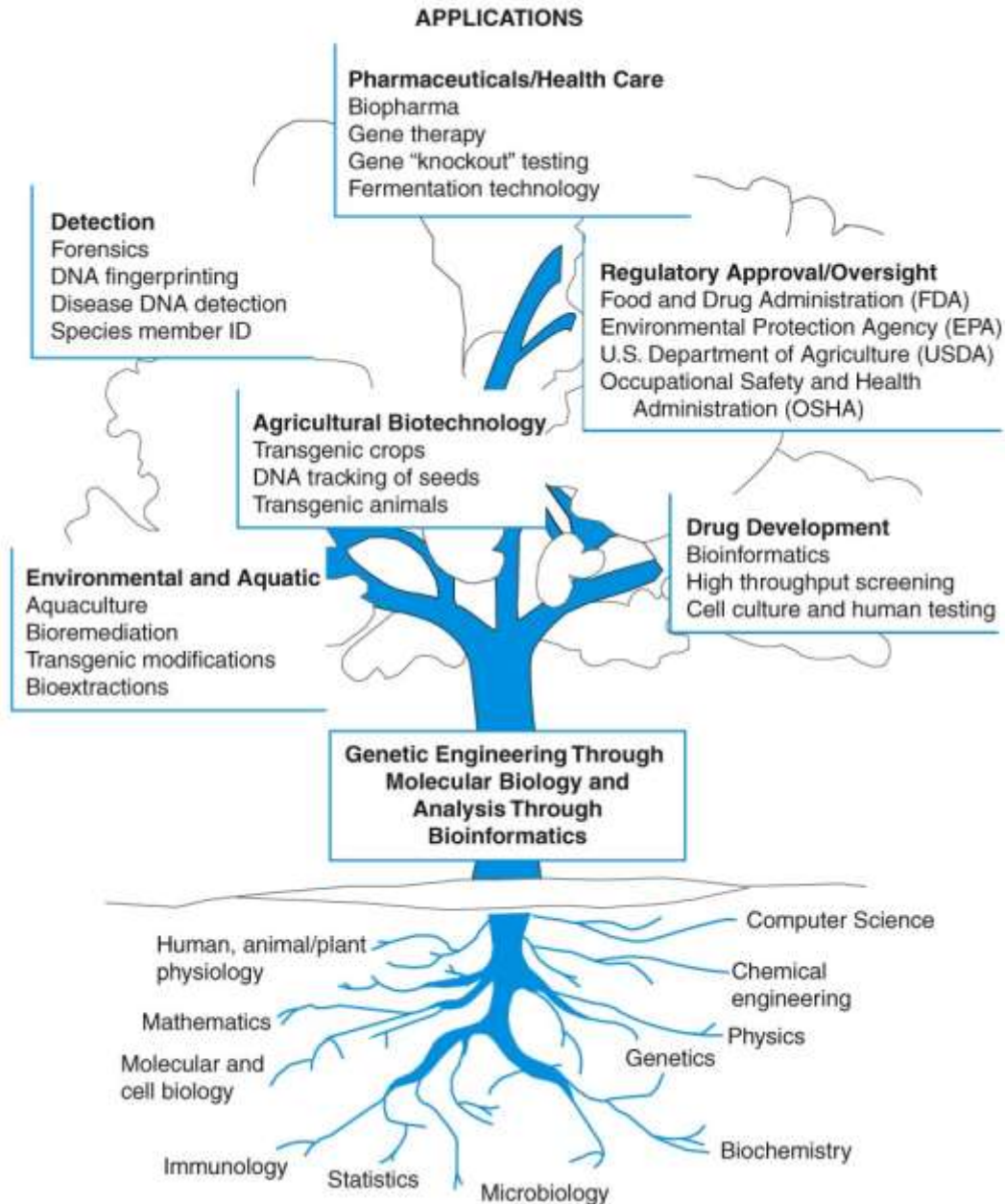
"Casper" zebrafish – made by selective breeding

- **What feature of Casper makes it a "model organism" to study migration of cancer cells compared to wildtype fish?**

Why Biotechnology?

- Sometimes only way to make some products
- Selectivity
- Less by-products
- Moderate reactor conditions
- One process versus multiple chemical steps in chemical synthesis (process intensification)
- Sustainable: reduced energy, reduced CO₂ emission (use of renewable resources), reduced waste (biodegradable), ...
- Economics (on a long term): fossil-based products become more expensive due to increased prices of crude oil; in IB biomass (agriculture and forest residues, energy crops, and algae) can be applied as raw materials

Biotechnology and What Does It Mean to You?



Biotechnology and What Does It Mean to You?

recombinant DNA technology started modern biotech as an industry

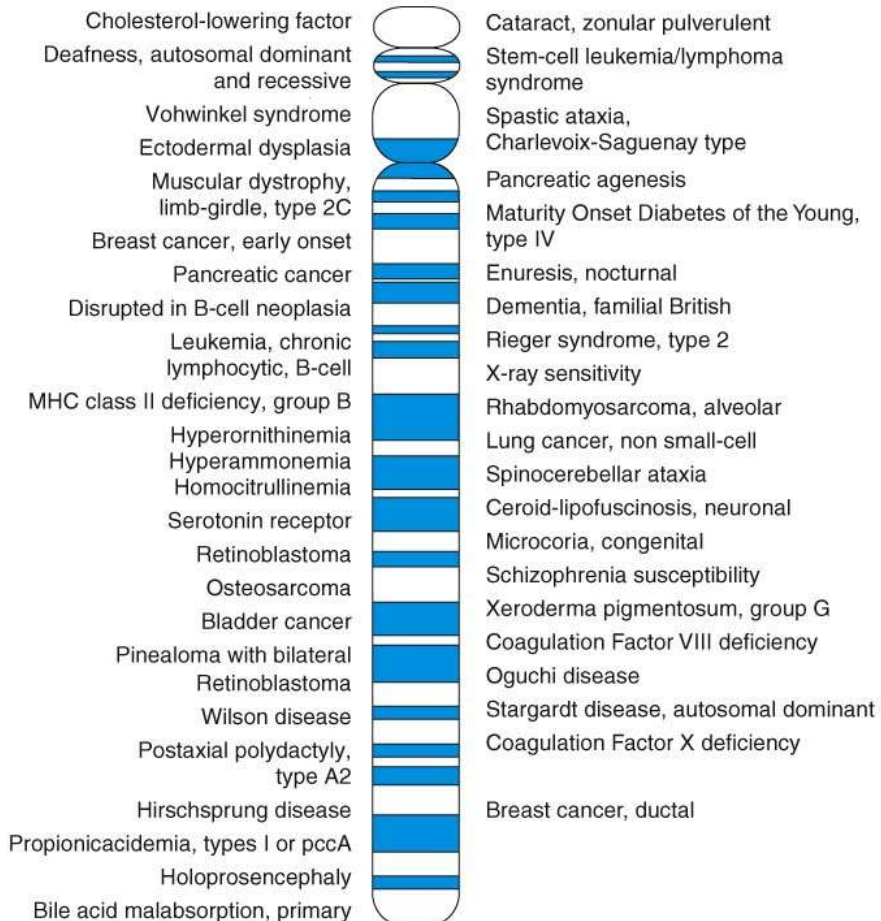
- Examples of applications
 - development of disease-resistant plants
 - food crops that produce greater yields
 - "golden rice" engineered to be more nutritious
 - genetically engineered bacteria that can degrade environmental pollutants

Biotechnology and What Does It Mean to You?

- See the two chromosomes below and determine which chromosome has more than one gene involved in promoting breast cancer.

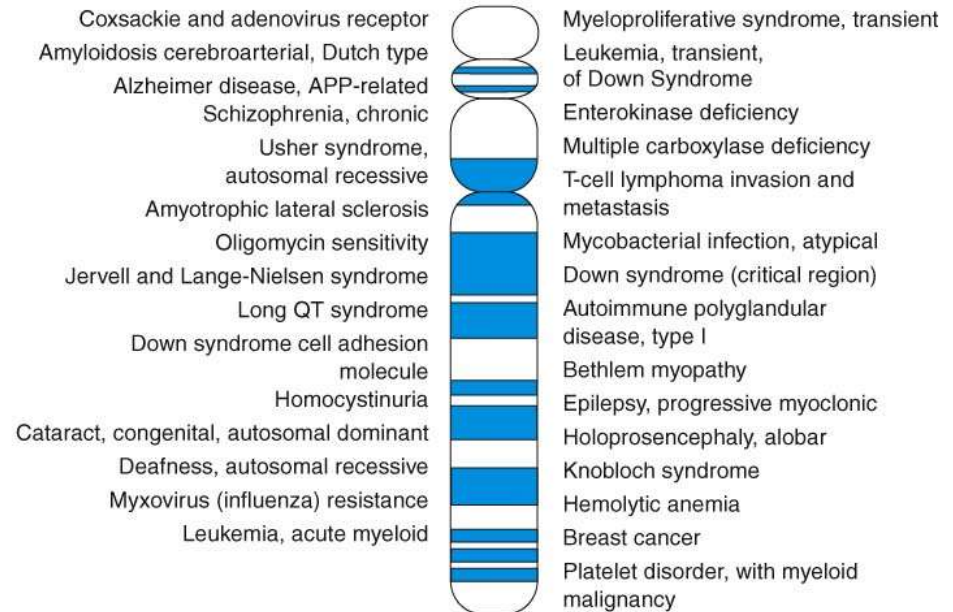
Chromosome 13

114 million bases



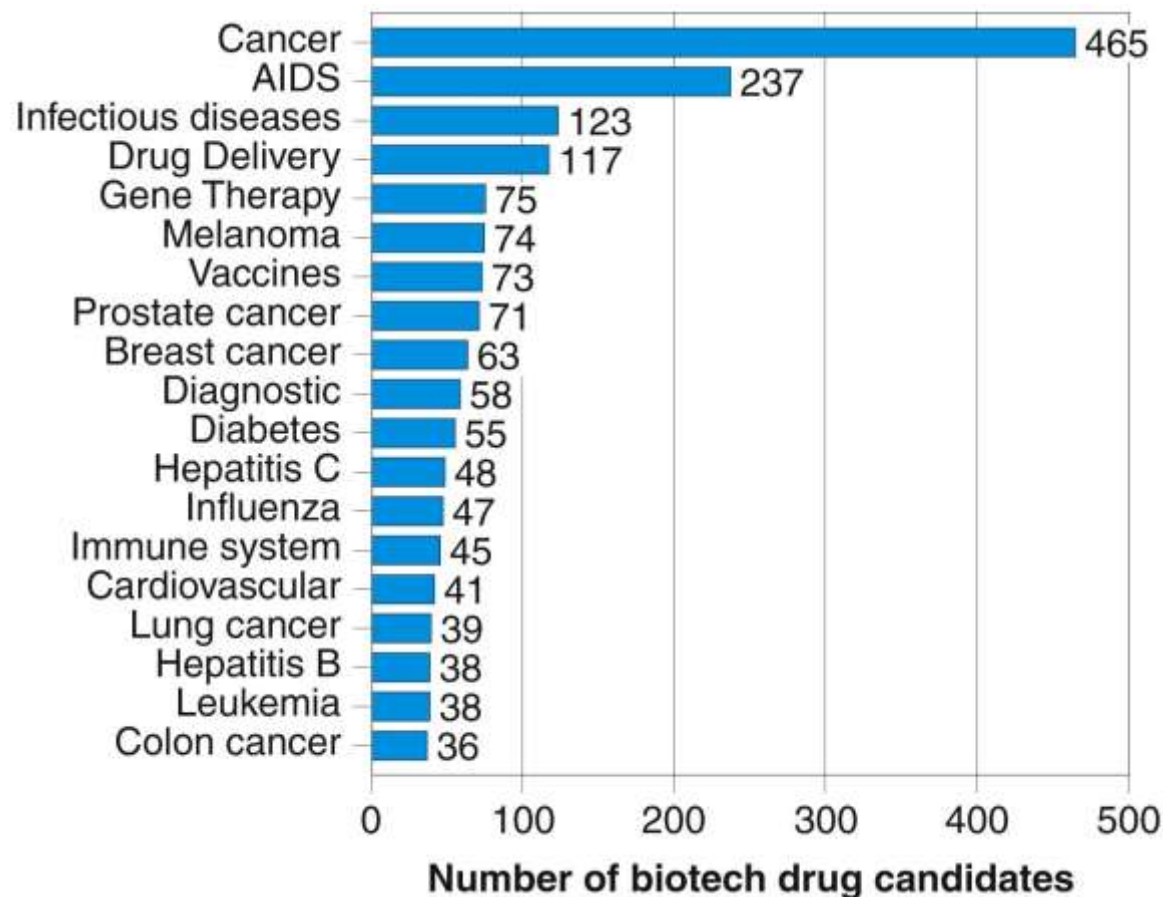
Chromosome 21

50 million bases



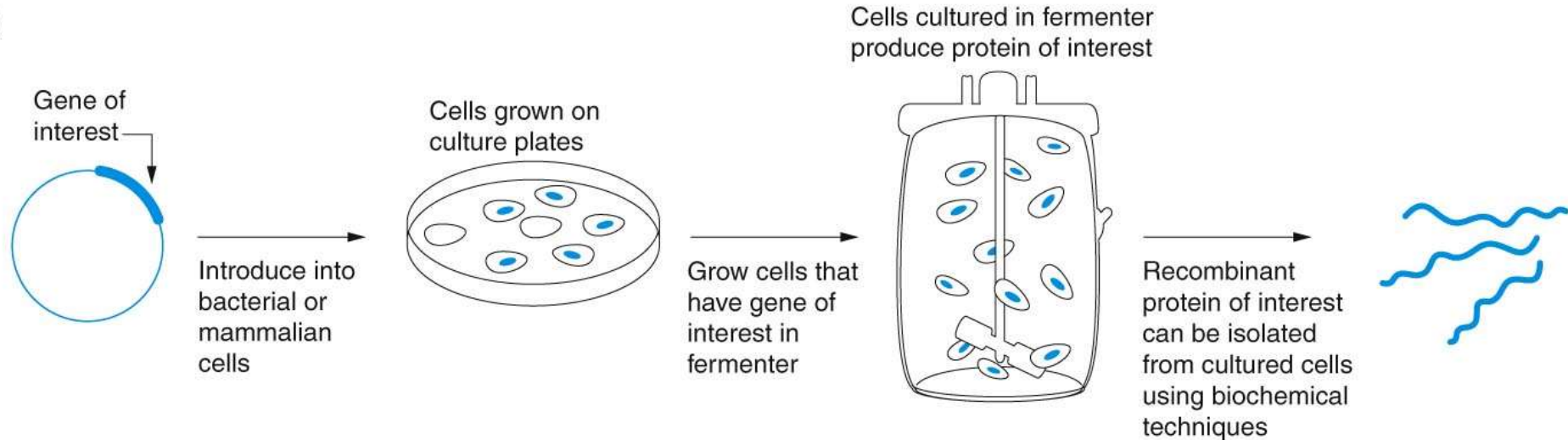
Biotechnology and What Does It Mean to You?

- Most drugs are developed to combat diseases affecting humans – Why?
- Which disease has the most drug candidates, Why?



Biotechnology and What Does It Mean to You?

- Use genetically modified cultured cells to make protein of interest



Biotechnology and What Does It Mean to You?

- **Products of Modern Biotechnology**
 - Example of **recombinant proteins**

TABLE 1.2 EXAMPLES OF PROTEINS MANUFACTURED FROM CLONED GENES

Product	Application
Blood factor VIII (clotting factor)	Treat hemophilia
Epidermal growth factor	Stimulate antibody production in patients with immune system disorders
Growth hormone	Correct pituitary deficiencies and short stature in humans; other forms are used in cows to increase milk production
Insulin	Treat diabetes
Interferons	Treat cancer and viral infections
Interleukins	Treat cancer and stimulate antibody production
Monoclonal antibodies	Diagnose and treat a variety of diseases including arthritis and cancer
Tissue plasminogen activator	Treat heart attacks and stroke

Types of Biotechnology

- Microbial Biotechnology
- Agricultural Biotechnology
- Animal Biotechnology
- Forensic Biotechnology
- Bioremediation
- Aquatic Biotechnology
- Medical Biotechnology
- Regulatory Biotechnology

Types of Biotechnology

- **Microbial Biotechnology** – manipulation of microorganisms such as yeast and bacteria
 - Create better enzymes
 - More efficient decontamination processes for industrial waste product removal
 - Used to clone and produce large amounts of important proteins used in human medicine

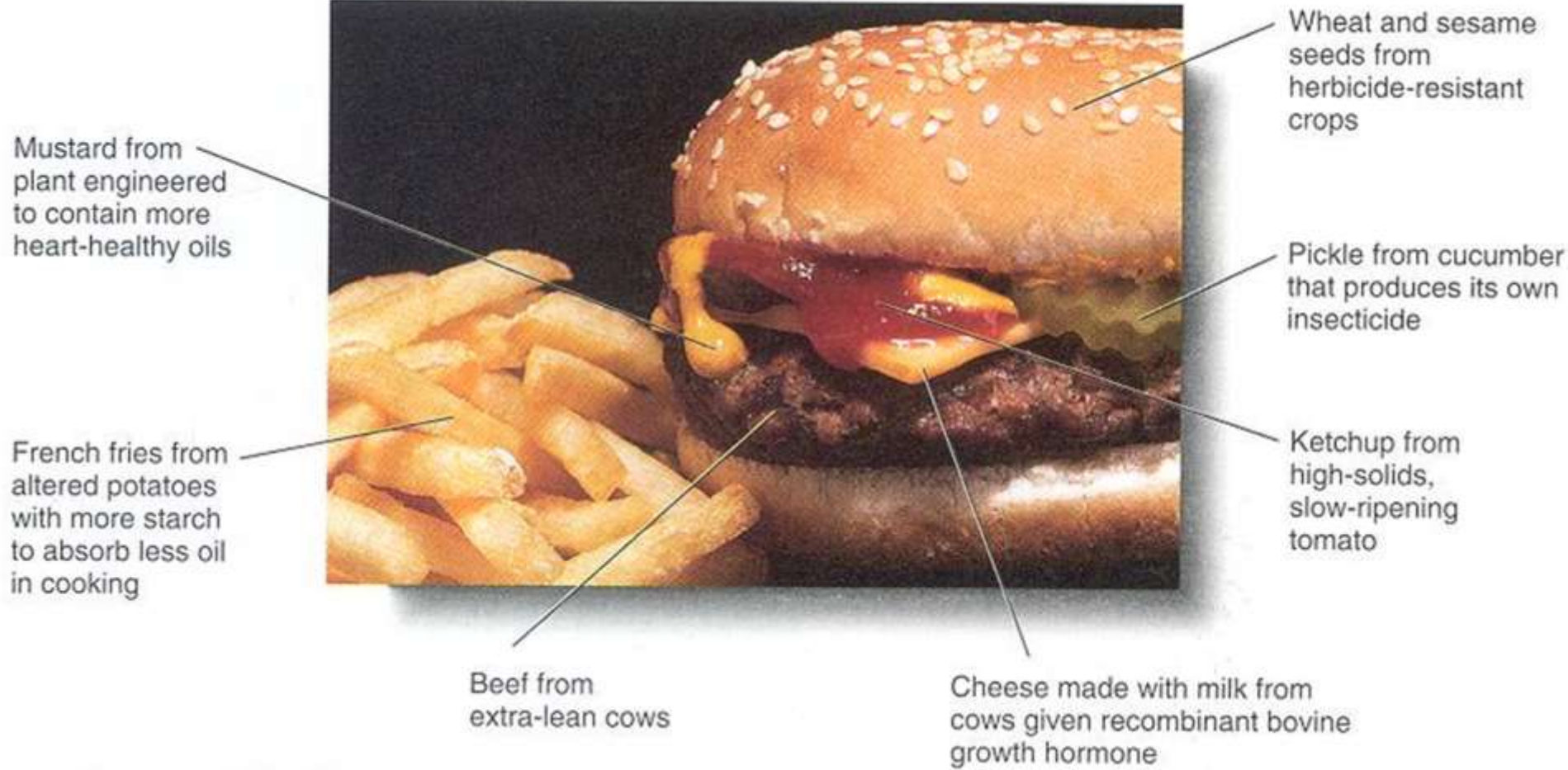
Examples of product from microbial conversion

Products	Typical micro-organism(s)	Approximate worldwide production [kg/year]
<i>Bulk organic products</i>		
Ethanol	<i>Saccharomyces cerevisiae</i>	$2 \cdot 10^{10}$
Acetone / butanol	<i>Clostridium acetobutylicum</i>	$2 \cdot 10^6$ (butanol)
<i>Biomass</i>		
Starter cultures	Lactic acid bacteria, baker's yeast	$5 \cdot 10^8$
Single-cell protein	e.g., <i>Candida utilis</i>	$0.5-1 \cdot 10^8$
<i>Organic acids</i>		
Citrate	<i>Aspergillus niger</i>	$2-3 \cdot 10^8$
Lactate		
<i>Amino acids</i>		
L-glutamate	<i>Corynebacterium glutamicum</i>	$3 \cdot 10^8$
<i>Antibiotics</i>		
Penicilline	<i>Penicillium chrysogenum</i>	$3-4 \cdot 10^7$
cephalosporines	<i>Cephalosporium acremonium</i>	$1 \cdot 10^7$
tetracyclines	<i>Streptomyces aureofaciens</i>	$1 \cdot 10^7$
<i>Note: The following overview is a non-exhaustive list of products. Source: Doran, 1995</i>		

Types of Biotechnology

- **Agricultural Biotechnology**

- Plants more environmentally friendly that yield more per acre (genetically engineered)
- Resistance to diseases and insects
- Foods with higher protein or vitamin content
- Drugs developed and grown as plant products
- These better plants ultimately reduce production costs to help feed the growing world population



Types of Biotechnology

- **Animal Biotechnology**

- Animals as a source of medically valuable proteins
 - Antibodies
 - Transgenic animals
- Animals as important models in basic research
 - Gene "knockout" experiments
 - Design and testing of drugs and genetic therapies
- Animal cloning
 - Source of transplant organs

Types of Biotechnology

- **Animal Biotechnology**

- **transgenic animal:** way to achieve large scale production of therapeutic proteins from animals for use in humans
- Female transgenic animals express therapeutic proteins in milk (contains genes from another source)
- Example: human genes coding for clotting proteins can be introduced into female goats for production of these proteins in their milk

Types of Biotechnology

- **Animal Biotechnology**

- **Gene knockout:**

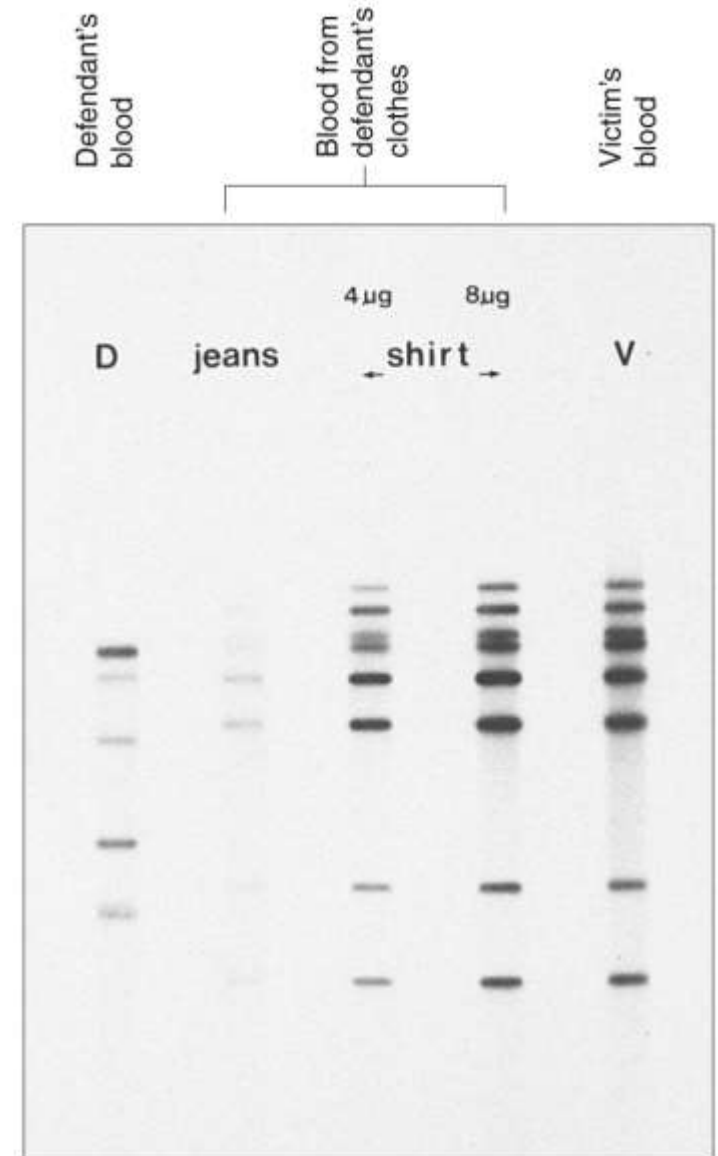
- Disrupt a gene in the animal and then look at what functions are affected in the animal as a result of the loss of the gene
 - This allows researchers to determine the role and function of the gene
 - Since humans are similar to rats and mice, gene knockout studies in rats and mice can lead to better understanding of gene function in humans.

Types of Biotechnology

- **Forensic Biotechnology**
 - DNA fingerprinting
 - Inclusion or exclusion of a person from suspicion
 - Paternity cases
 - Identification of human remains
 - Endangered species
 - Tracking and confirmation of the spread of disease

Types of Biotechnology

- **Forensic Biotechnology**
- **Based on DNA results from this gel, did the defendant commit this crime?**



Types of Biotechnology

- **Bioremediation**

- The use of biotechnology to process and degrade a variety of natural and manmade substances
 - Particularly those that contribute to environmental pollution
- Example – stimulated growth of bacteria that degrade components in crude oil
 - 1989 Exxon Valdez oil spill in Alaska
 - 2010 Deep Water Horizon spill promoted research into natural oil-degrading organisms and enzymes

Types of Biotechnology

- Bioremediation – adding nutrients to stimulate growth of bacteria to clean up oil spill



Types of Biotechnology

- **Aquatic Biotechnology**
 - **Aquaculture** – raising finfish or shellfish in controlled conditions for use as food sources
 - 50% of all fish consumed by humans worldwide
 - **Genetic engineering**
 - Disease-resistant strains of oysters
 - Vaccines against viruses that infect salmon and other finfish
 - Transgenic salmon that overproduce growth hormone
 - **Bioprospecting**: rich and valuable sources of new genes, proteins and metabolic processes with important applications for human benefits
 - Marine plankton and snails found to be rich sources of antitumor and anticancer molecules

Types of Biotechnology

- **Aquatic Biotechnology**
- **Why create transgenic salmon overproducing growth hormone?**



transgenic

normal

Two different salmon

- **How does this modified salmon help humans?**

Types of Biotechnology

- **Medical Biotechnology**

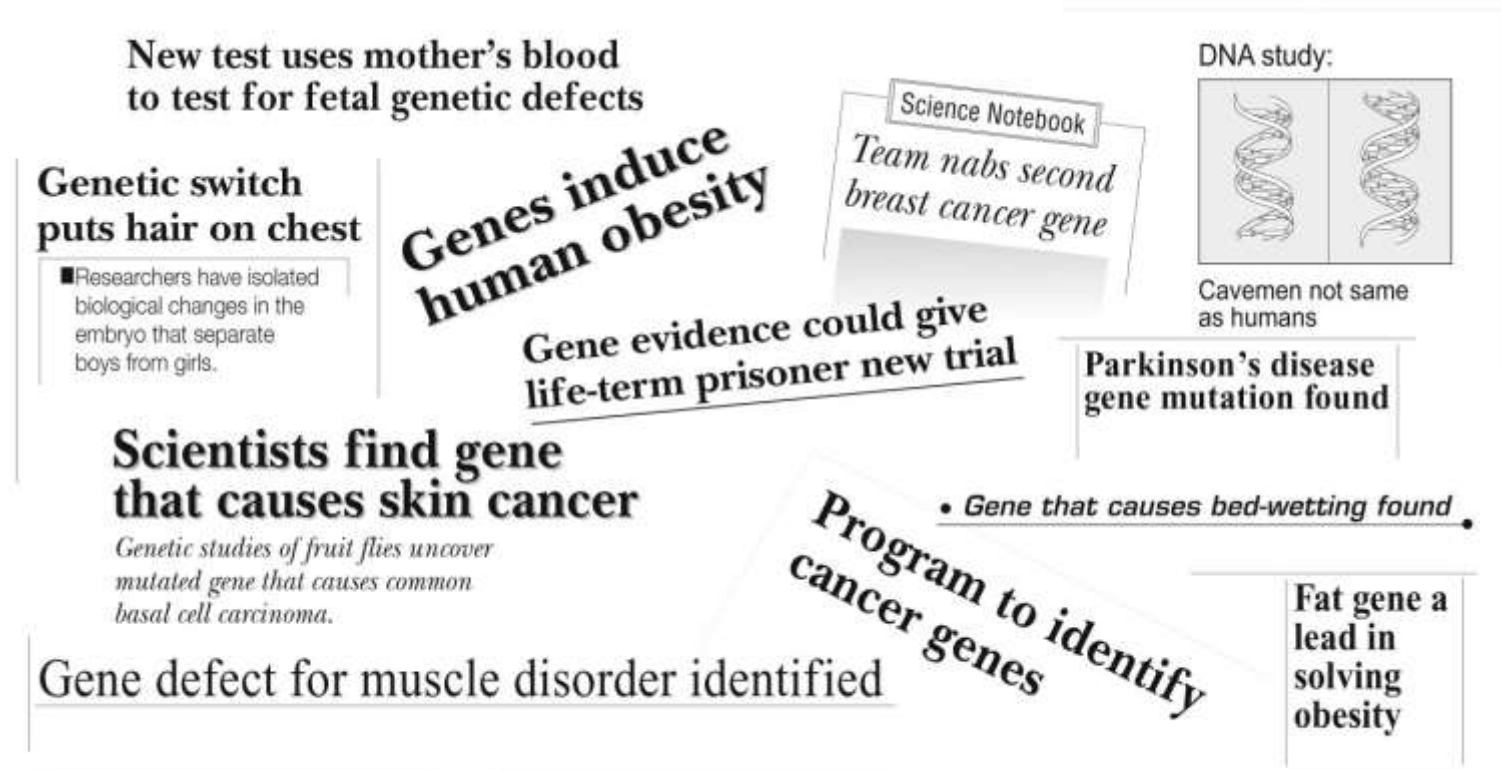
- Involved with the whole spectrum of human medicine
 - Preventive medicine
 - Diagnosis of health and illness
 - Treatment of human diseases
- New information from Human Genome Project
 - Gene therapy
- Stem cell technologies

Types of Biotechnology

- **Stem cells** – grown in lab and then treated with different chemicals to allow them to develop into specific kinds of tissues needed for transplant
- Current use: stem cells are used for diabetes; spinal cord injuries

Types of Biotechnology

- **Medical biotechnology**
 - **Genes are headline news items**



Types of Biotechnology

- **Regulatory Biotechnology**
 - **Quality Assurance (QA)**
 - All activities involved in regulating the final quality of a product
 - **Quality Control (QC)**
 - Part of QA process that involves lab testing and monitoring of processes and applications to ensure consistent product standards
 - Together QA and QC ensure that biotechnology products meet strict standards for purity and performance
- **Why as a consumer should you care about a product undergoing intense regulations?**

Biological Challenges of the 21st Century

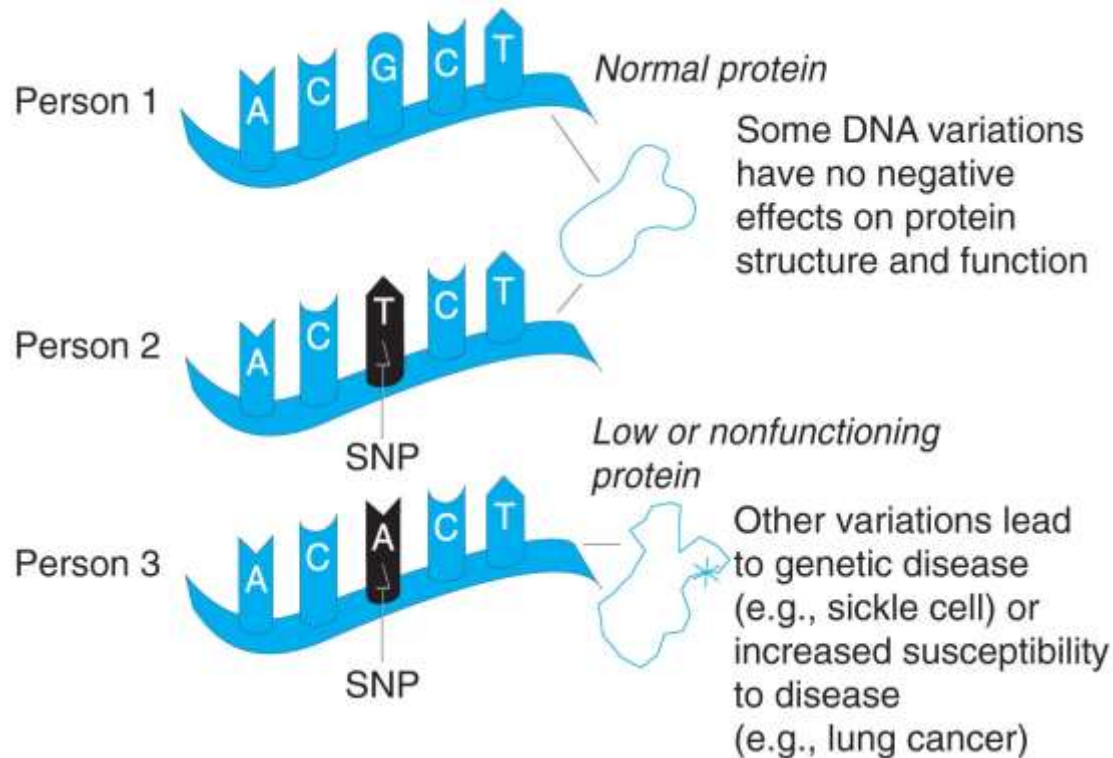
- **How will medical biotechnology change our lives in the years ahead?**
 - **Human Genome Project**
 - Research on the function of human genes and controlling factors that regulate genes
 - **Human proteome**
 - Collection of proteins responsible for activity in a human cell

– **Single Nucleotide Polymorphisms (SNPs)**

- Single nucleotide changes (mutations) in DNA sequences that vary from individual to individual
- These variations are the cause of some genetic diseases (sickle cell anemia)
- SNPs will help identify genes involved in medical conditions including arthritis, stroke, cancer, heart disease, diabetes, and behavioral and emotional illnesses
- **Example of SNPs and breast cancer**
- Identification of SNPs in BRCA1 and BRCA2 genes involved in promoting breast cancer led to development of better targeted treatments for people who have those specific gene mutations

Biological Challenges of the 21st Century

- **Example of how we can benefit from the human genome project**



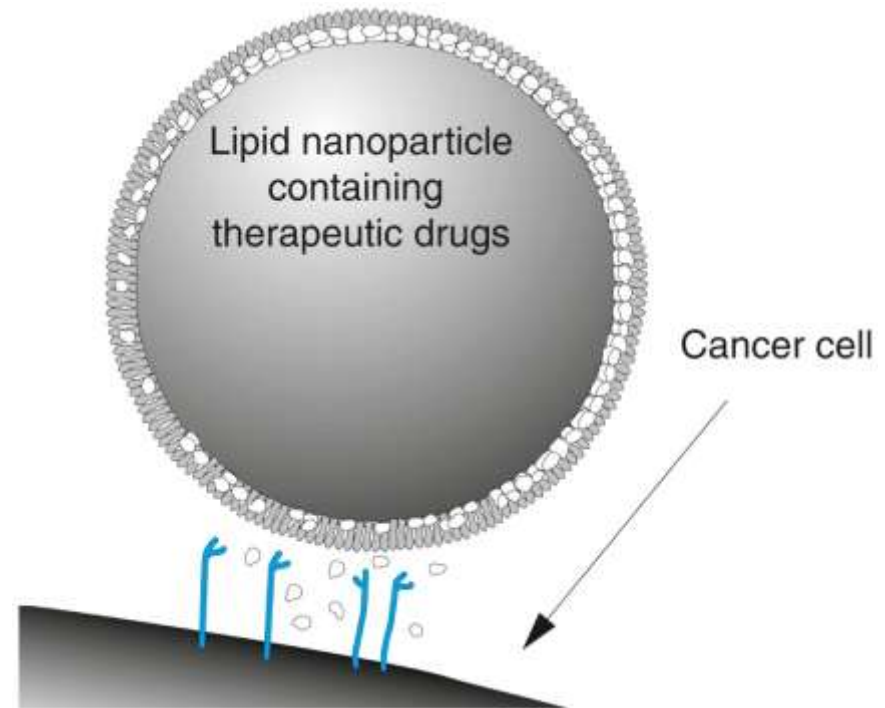
- **Based on the figure, why doesn't person 2 develop a genetic disease due to the SNP (G → T)?**

Biological Challenges of the 21st Century

- **How will medical biotechnology change our lives in the years ahead?**

- **Nanotechnology**

- Applications that incorporate extremely small devices
- Small particles that can deliver drugs to cells



Biological Challenges of the 21st Century

- **Gene therapy technology**
 - Replacing or augmenting defective genes with normal copies of the gene
 - Still have barriers to overcome before this technology becomes safe and effective
 - Obstacles include:
 - How can normal genes be delivered to virtually all cells in the body?
 - What are the long-term effects of introducing extra genes in humans?
 - What must be done to ensure the proper protein is made after the genes are delivered to the body?

Biological Challenges of the 21st Century

- **Small interfering RNA (siRNA)** is emerging technology to silence genes that are involved in disease progression

Biological Challenges of the 21st Century

- **Stem cell technology**

- Stem cells are immature cells that grow and divide to produce different cell types
- Most stem cells are from embryos called embryonic stem cells (ESCs) but they are controversial since the process involves death of an embryo
- Some stem cells are from adult cells (ASCs)
 - Either type of stem cell can be coaxed to grow into cells of interest to replace damaged tissue or failing organs (liver, pancreas, retina)

- **Embryonic vs. adult stem cells?**

Biotechnology in the 21st Century

- ESCs can give rise to many types of differentiated cells

