Biotechnology and Genomics

Outline

- The OLD way: Selective Breeding
- Cloning
  - Recombinant DNA Technology
  - Restriction Enzyme
  - DNA Ligase
  - Polymerase Chain Reaction
- Biotechnology Products
- Genomics
- Gene Therapy

Selective Breeding

- **Selective Breeding** occurs when humans allow only those organisms with desired characteristics to produce to the next generation

- Takes advantage of naturally occurring genetic variations to benefit humans
Selective Breeding

- The first application of genetics
- First evidence of selective breeding: domesticating Dogs 12,000 years ago
- Now there are hundreds of species of dogs (150+ recognized by the AKC)

Selective Breeding

- Other examples:
  - Mendel practiced selective breeding
  - Most domesticated animals are bred for specific traits (cows, horses, fish)
  - Agriculture: most crops are selectively bred (rice, corn)

Selective Breeding in Rice

In the rice crop on the left (IR-8) is a high-yield, semi-dwarf variety of rice. The shorter, stiffer stalks of this variety allow the plant to support larger heads of grain without falling over.

This Variety is a cross between the other two pictured varieties: PETA from Indonesia and DGWG from China.
Biotechnology

- **Biotechnology**: The application of genetics to solve problems and make useful products
- Biotechnology is an emerging industry that is changing the way we interact with the living world.

Cloning

- **Cloning** is the production of genetically identical cells or organisms.
- Dolly, the first cloned mammal, is pictured to the right.
  - Dolly had offspring
  - Dolly died at age 6 from progressive lung disease.

Cloning

- **1952**: Tadpole first organism to be cloned
- **1996**: Dolly the Sheep is the first mammal to be cloned from an adult organism
- **1997**: Mouse cloned
- Since then:
  - Cow, goats, pigs, cats, rabbits, a mule, a gaur, and a horse
Genetic Engineering

- **Genetic Engineering** occurs when the genetic make-up of an organism is altered.
- The gene that makes a firefly illuminate has been genetically inserted into cells of this plant.
- An organism that contains genes from an entirely different organism is known as a **Transgenic Organism**.

Genetically Modified Organisms

- **AKA. GMO**
- Organisms are modified to:
  - Increase taste and quality
  - Enhance size
  - Increase yield (harvest in crops, milk, eggs...)
  - Increase resistance to disease or pesticides
  - Increase nutrition

Examples of GMOs

- **Bt Corn**
  - Pest resistant, 5-10% increase yield
- **Golden Rice**
  - Higher quantities of Vitamin A, Iron
- **GM Tomatoes**
  - Tomato reaches full flavor and color on vine without rotting
- **E.Coli and Human Insulin**
  - Mass produce Human Insulin for Diabetic Patients
- **GM Factor 8**
  - Produce clotting factor for hemophilia patients
GMOs: Ethics and Safety Issues

- Potential Health Impacts
  - Allergens
  - Labeling of GMOs is not mandatory in the US.

- Unknown Environmental Impacts
  - Tampering with nature
  - Transfer of genes to other organisms is possible

Technologies Used

- DNA Cloning
- PCR
- Sequencing

DNA Cloning: Recombinant DNA Technology

- Recombinant DNA contains DNA from two or more different sources
  - Requires:
    - A vector
    - Introduces rDNA into host cell
    - Plasmids (small accessory rings of DNA from bacteria) are common vectors
  - Two enzymes to introduce foreign DNA into vector DNA
    - A restriction enzyme - cleaves DNA, and
    - A DNA ligase enzyme - seals DNA into an opening created by the restriction enzyme
**DNA Cloning:**
**Polymerase Chain Reaction (PCR)**
- Amplifies a targeted sequence of DNA
- Allows thousands of copies to be made of small samples of DNA
- Requires:
  - DNA polymerase
  - A supply of nucleotides for the new, complementary strand

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**Applications of PCR:**
**Analyzing DNA Segments**
- DNA can be subjected to DNA fingerprinting
  - Treat DNA segment with restriction enzymes
  - A unique collection of different fragments is produced
  - Gel electrophoresis separates the fragments according to their charge/size
  - Produces distinctive banding pattern
- Usually used to measure number of repeats of short sequences
- Used in paternity suits, rape cases, corpse ID, etc.
Biotechnology Products: Transgenic Bacteria

- Transgenic organisms have had a foreign gene inserted into their genetic make-up
- Transgenic Bacteria
  - Insulin, Human Growth Hormone
  - Oil-Eating Bacteria
  - Metals Collection
  - Promote plant health

Biotechnology Products: Transgenic Plants and Animals

- Transgenic Plants
  - Agricultural Crops
    - Human Hormones
- Transgenic Animals
  - Vortex Mixing:
    - Many types of animal eggs have taken up the gene for bovine growth hormone (bGH)
    - The procedure has been used to produce larger fishes, cows, pigs, rabbits, and sheep
  - Gene Pharming:
    - Use of transgenic farm animals to produce pharmaceuticals
    - Genes coding for therapeutic & diagnostic proteins are incorporated into an animal's DNA
    - The proteins appear in the animal's milk
    - Plans are to produce drugs to treat:
      - Cystic Fibrosis
      - Cancer
      - Blood diseases, etc.

Transgenic Mammals
Human Genome Project

- Genome - All the genetic information of an individual (or species)
- Goals of Human Genome Project
  - Determine the base pair sequence
  - Working draft
  - Construct a map showing sequence of genes on specific chromosomes
  - Other species in final stages

The Human Genome Project

- **The Human Genome Project**: An ongoing effort to analyze the human DNA sequence
- The human genome contains 3 Billion basepairs.
- 1990 - Sequencing of the human genome began
- 2000 – “working draft” of HG complete
- 2003 – Human Genome sequence finished
- Today – In-depth analysis of chromosomes continues
  - Scientists are working on analyzing the human genome
The Human Genome Project

- Purpose of the Human Genome Project:
  - Determine the base pair sequence
  - Identify all genes in the Human Genome (20,000-25,000 genes)
  - Create a database of the information
  - Determine the exact location and function of human genes

HapMap Project

- People inherit patterns of sequence differences, called haplotypes
  - If one haplotype of a person has an A rather than a G at a particular location in a chromosome, there are probably other particular base differences near the A
  - Genetic data from African, Asian, and European populations will be analyzed
  - A HapMap is a catalog common sequence differences that occur in a species
    - The goal of the project is to link haplotypes to risk for specific illnesses
    - May lead to new methods of preventing, diagnosing, and treating disease

Genetic Profile

- The complete genotype of an individual
  - This is the person’s genetic profile
  - A way of studying how genes work together to control the phenotype
    - Analyze the genetic profile of many individuals
    - Compare their profiles to their phenotypes
  - DNA chips that will rapidly produce a person’s genetic profile will soon be available
    - Need only a few cells
      - The DNA is removed, amplified by PCR, and then cut into fragments that are tagged by a fluorescent dye
      - The fragments are applied to a DNA chip, and the results are read
Proteomics

- The study of the structure, function, and interaction of cellular proteins
- At least 25,000 of our genes are translated into proteins
- The sum total of these proteins is called the human proteome
- Understanding protein function is essential to the development of better drugs
- Correlate drug treatment to the particular genome
- Increase efficiency and decrease side effects
- Once the primary structure of these protein is known
- It should be possible to predict their tertiary structure
- Computer modeling of the tertiary of these proteins is an important part of proteomics

Bioinformatics

- The application of computer technologies to the study of the genome
- Genomics and proteomics produce raw data
- These fields depend on computer analysis to find significant patterns in the data
- Scientists hope to find relationships between genetic profiles and genetic disorders
- New computational tools will be needed to accomplish these goals
Gene Therapy

- The insertion of genetic material into human cells for the treatment of a disorder
  - Ex Vivo
    - Children with Severe Combined Immunodeficiency
    - Bone Marrow Stem Cells
  - In Vivo
    - Cystic Fibrosis
    - Nasal / Respiratory Spray

Genetic Testing

- Genetic tests are available to test for genetic disorders
  - Screen parents to see if they are carriers
  - Prenatal Screening
  - Newborn Screening
  - Pre-symptomatic testing for adult-onset genetic disorders (Huntington's Disease, risk of cancers, Alzheimer's)
Genetic Testing

- Benefits
  - Ensures accurate diagnosis
  - Possibility to Improve lives
  - Directs toward appropriate treatment

- Problems
  - Some people with genetics for disorder never develop the disorder
  - Don't take into consideration environmental factors of other genes that could influence
  - Ethical issues…..

Your Responsibility

- The goal of biology is to understand the nature of life
- As our knowledge of biology increases, so does our ability to manipulate living things, including ourselves
- It is your responsibility to ensure that the tools of science are used wisely!!!