DARWIN 2009
Exploration is Never Extinct

SEPA SCIENCE EDUCATION PARTNERSHIP AWARD NCRR NATIONAL INSTITUTES OF HEALTH

DNA *and Evolution*

Bacteria Domain

Plasmid is a double-stranded circular DNA molecule. It's smaller and separate from chromosomal DNA. It can be found in cells in all three domains: bacteria, archaea and eukarya!

Average Genome size of bacteria
3.7 million base pairs

An organism's collection of DNA is called its **genome**. In a multicellular organism, each cell has a copy of the full genome. The size of genomes varies greatly across the domains of life. Eukaryotic genomes have the most variation in size, varying between 12 million to 34 billion base pairs!

Genotype usually refers to a particular sequence or gene and how it is different in each organism.

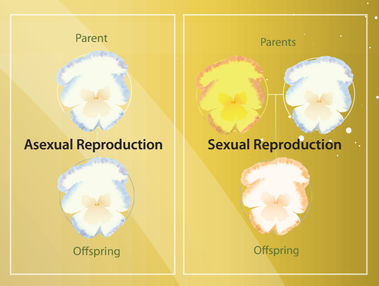
Average Genome Size of Eukaryotes
3 billion base pairs

A **mutation** is a change in the sequence of nucleotides. A mutation can be a change of a single nucleotide, or the deletion or insertion of whole sequences! Mutations can cause changes in the **phenotype** of an organism: the way it grows, looks and behaves.

So, mutation is one mechanism that creates **variation** in nature!

Bacteria can pass genetic material to each other through **conjugation!** This genetic material might bring new traits.

Eukarya Domain



Organisms reproduce to create offspring, passing their genetic information on to the next generation. This is called **inheritance!** The radial branches of the Spiral indicate the genetic material of the population at each moment in time. The genetic material gets passed from one generation to the next through reproduction.

In **asexual reproduction,** a parent organism or cell creates offspring with the same DNA as the parent. In **sexual reproduction,** DNA from two parents is combined in their offspring. In this case, the offspring might look different from both parents, since it has characteristics of both.

Protist Kingdoms

Early eukaryotes engulfed bacteria that lived on inside the cell, evolving into organelles. The bacterial DNA added to the host's genome. This process is called **endosymbiosis**, and is thought to have occurred many times in the evolution of life.

Secondary endosymbiosis gave chloroplasts (and photosynthesis) to other protists.

Engulfed bacteria originated the modern **mitochondria**, the powerhouse of the eukaryotic cell.

Some bacteria developed the ability to get energy from the sun - with photosynthesis! Engulfed bacteria of this kind evolved into the **chloroplast** in modern eukaryotic cells.

Archaea Domain

Average Genome size of Archaea
2.4 million base pairs

LUCA is the Last Universal Common Ancestor!

We know from the shared characteristics of all livings things that LUCA must have had:

- DNA with two long sequences of molecules called **nucleotides.** Each nucleotide had a sugar, a phosphate and one of four bases: **adenine** (A), **cytosine** (C), **guanine** (G) and **thymine** (T). This sequence of four letters codes all aspects of every organism! The two strands of DNA are held together by strong bonds that form between the bases on each side.

- Each group of 3 bases forms a **codon**, and indicates one of **20 amino acids**. The DNA sequence is copied to RNA. The cell uses the RNA molecule to put together the appropriate amino acids to build **proteins**. Proteins build and regulate all aspects of cells!

RNA

DNA

Eukaryotes
1900 million years ago

Multicellular Eukaryotes
1000-700 million years ago

Origin of Life
3400 million years ago

500 million years ago

Today!

Future?

Plant Kingdom

Hybridization is when two different species or groups produce offspring. The offspring combines characteristics of the two parents, and therefore of the two groups!

It is now thought that hybridization plays a major role in the evolution of many plants, including wild sunflowers, contributing both to the adaptation of the species and to creating entirely new species!

The vertebrate genome was fully duplicated twice!

New genes can come into existence by a process known as **gene duplication.**

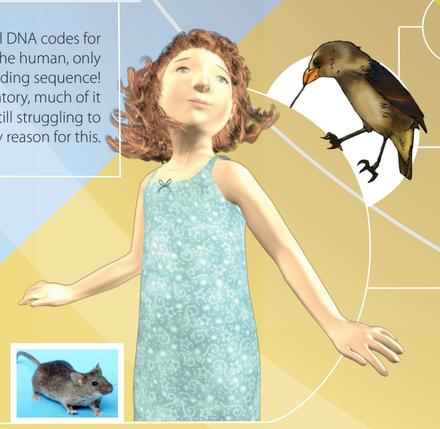
Gene duplication occurs when an organism's DNA is copied incorrectly, and an extra copy of a gene is inserted into the genome. This extra copy allows the organism's genome to "play around" with the function of that gene, while still retaining a functional copy of that gene. This new gene can take on a new function, completely separate from the original gene's function!

DNA is full of junk!

Some parts of DNA code for useful things like proteins and functional RNA – these are called **exons**, and are made of genes. The rest are called **introns**. Introns can have regulatory functions: they help the cells know when to make or stop making new proteins and RNA. But introns also include random sequences that appear to have no use - **junk DNA!** Some of these sequences are called **transposable elements**, because they can copy and insert themselves randomly in the genome.

About 90% of bacterial DNA codes for something useful, but in the human, only about 1.5% of DNA is actual coding sequence! While some of the rest is regulatory, much of it is "junk DNA!" Scientists are still struggling to find an evolutionary reason for this.

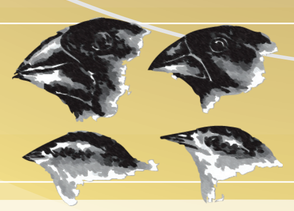
Animal Kingdom



How can humans and mice be 95% alike?

Because 95% of the exons and introns in humans and mice are **homologs**. This means that 95% of the exons and introns serve a similar function even though they have different sequences. One major reason for the differences we see between mice and humans is that each gene is regulated differently in each organism.

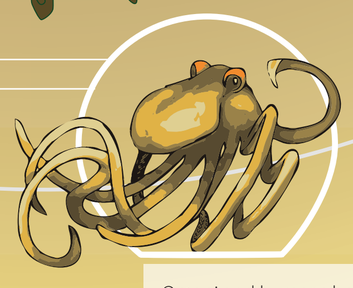
Being 95% alike means that humans and mice are very closely related! Exons and introns are conserved over time because they are needed for the health of the organism. Scientists can determine how two organisms are related by comparing these sequences in their genomes. Very similar genomes mean that the two species are closely related!



There is so much variety in every species!

Darwin found 12 different species of finches in the islands of the Galapagos. He realized that one original species of finches had traveled to these islands. This group included many individuals that were all slightly different, some bigger or smaller, or with slightly different beaks. The particular environment in each island selected which variants were most fit by natural selection. Over time, the original population evolved into distinct species as different as the birds above!

Darwin knew that this variety was needed for species to evolve through natural selection. But he didn't know where this variation came from! Now we know that DNA inheritance and reproduction explain a lot of the variation we can observe.



Octopi and humans both have eyes - does that mean they share a recent common ancestor?

Actually, no. Scientists compare the characteristics of organisms to try to understand how closely related they are, but looks can be deceiving!

Further research, including genetic data, has shown that mollusks, like the octopus, and vertebrates, like the human, separated around 570 million years ago, before either type had eyes! So the eyes of octopuses and the eyes of sea lions developed independently of one another. We call this **convergent evolution**.

Fungi Kingdom

Scientists don't know what to do with viruses!

While we're not sure if viruses are alive, they are more common and diverse than any living organism. Viruses can infect cells, and inject their DNA into the host cell. They also can extract their DNA out and travel to another cell or organism. We find bits of viral DNA in all living things. Sometimes, it appears to even help the cell! And sometimes, viruses take DNA from one cell and inject it into another, so we've been able to find the DNA of one organism in the cell of another. We call this **horizontal transfer**!

As our knowledge of viruses increases, it challenges the idea that DNA only passes between organisms by inheritance! How much does **horizontal gene transfer** influence evolution?

VIRAL INFECTION

1 - Virus approaches a cell to infect it.

2 - The virus injects its DNA into the cell's DNA.

3 - The virus uses the cell to make copies of itself.

4 - The virus can kill the cell to release its copies. But sometimes, the cell survives with some extra viral DNA!

Joana Ricou - Art Director/Artist, Brinley Kantorski - Research, John A. Pollock - Executive Director