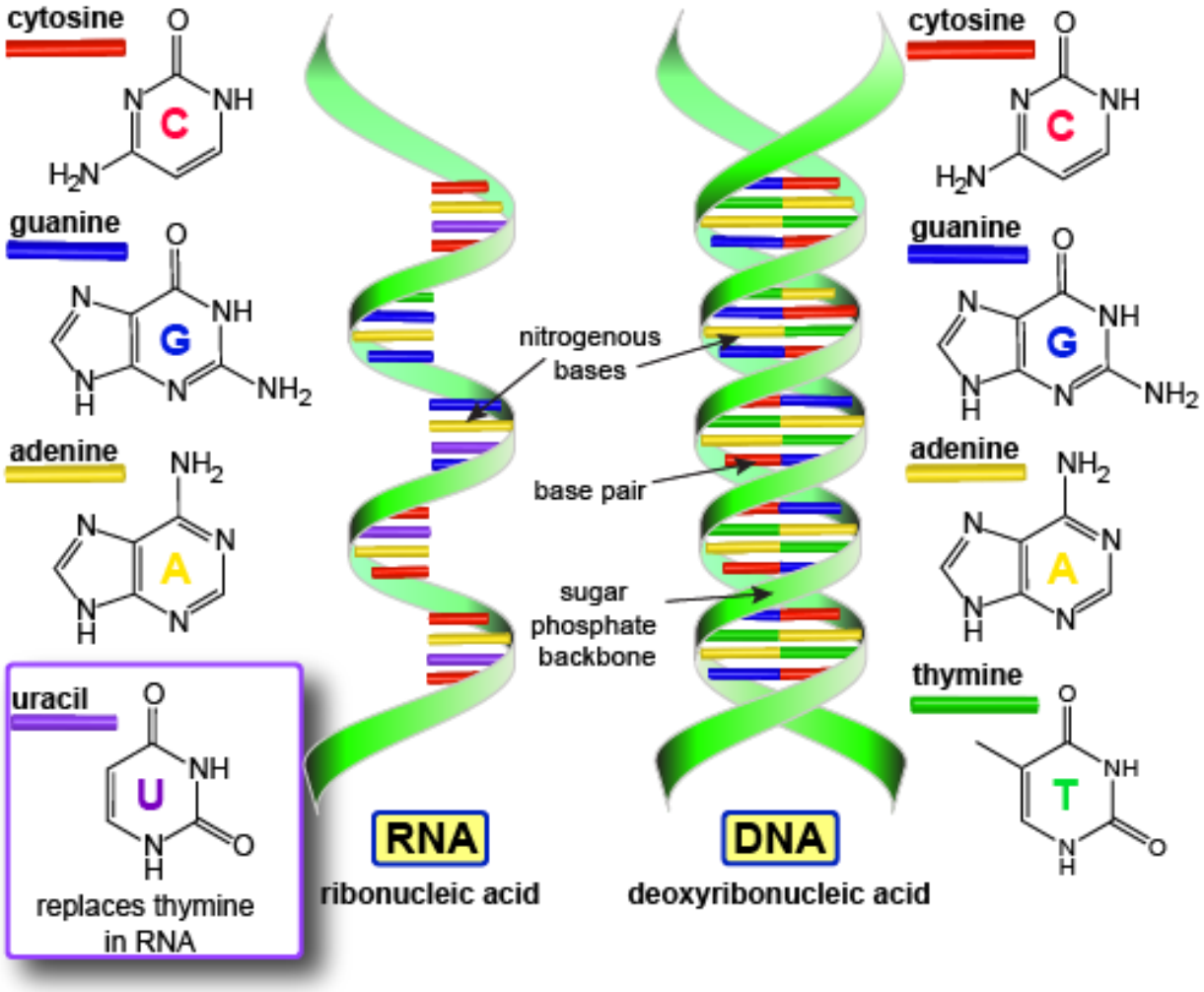
Nucleic Acids: Hereditary Material

All cells <u>store information</u> required to build and maintain the cell (*genetic information*) and <u>constantly use it</u>.



Nucleic acids are the molecules that

contain (Deoxyribonucleic acid, DNA)

and

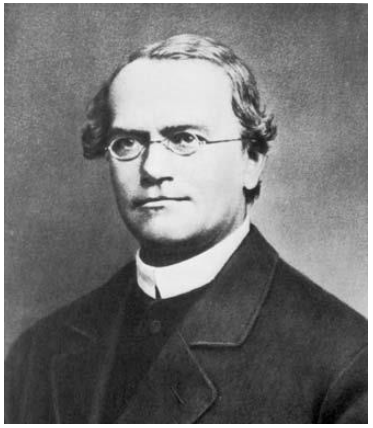
help express (ribonucleic acid, RNA)

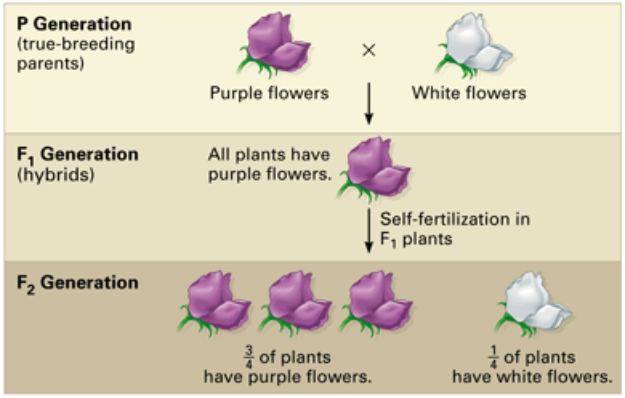
this information.

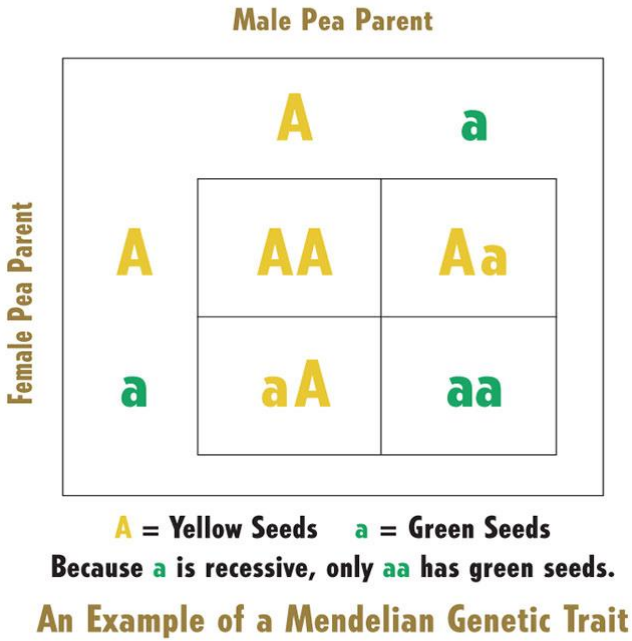
Laws of Mendelian Inheritance

Gregor Mendel, 1856-1863:

pea plant experiments



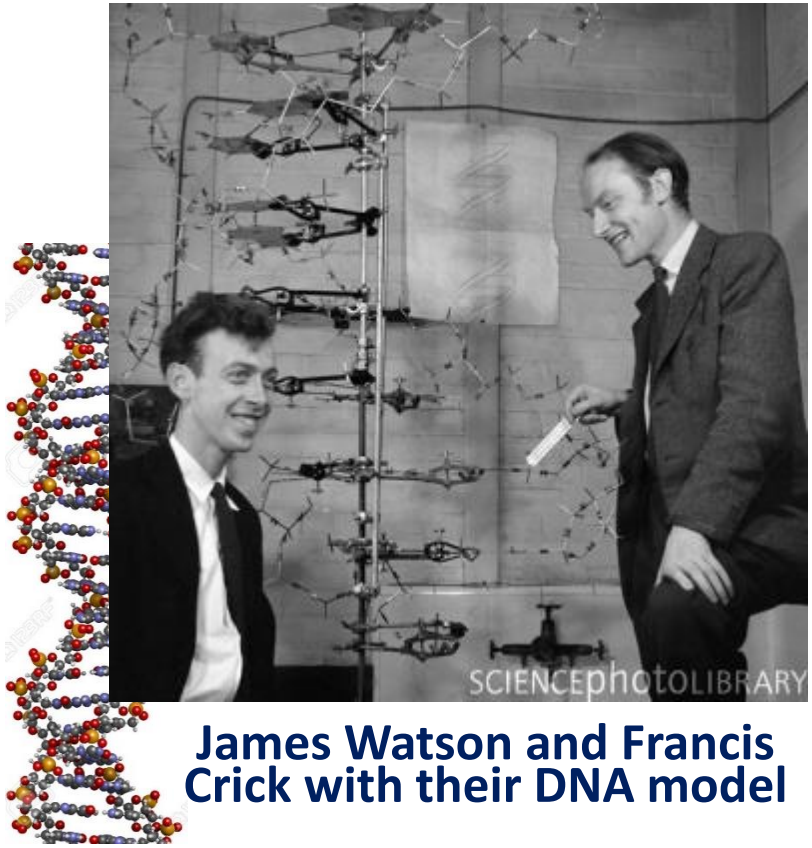




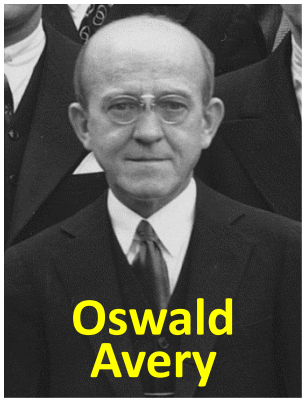
- **Cultivated and tested** some *29,000 pea plants* in the monastery's 2 hectares (4.9 acres) experimental garden.
- Worked with <u>seven characteristics</u>: plant height, pod shape and color, seed shape and color, and flower position and color.
- Law of Segregation: one random *allele* (gene variation) from each parent.
- Law of Independent Assortment: alleles for different traits are independent.
- Law of Dominance: some alleles are dominant while others are recessive; an organism with <u>at least one dominant</u> allele will <u>display the effect of the dominant</u> allele.
- **"Father of modern genetics"**

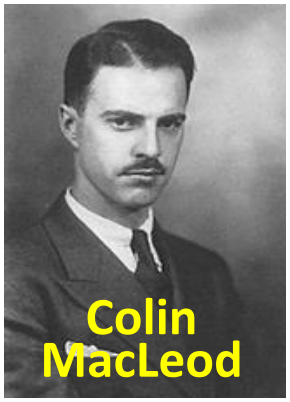
DNA Discovery

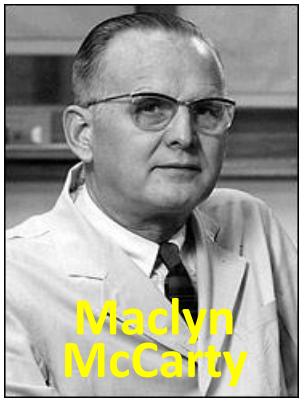
- Swiss physician Friedrich Miescher discovered DNA ("nuclein") in 1869, athough scientists did not understand what it was until…



James Watson and Francis Crick with their DNA model







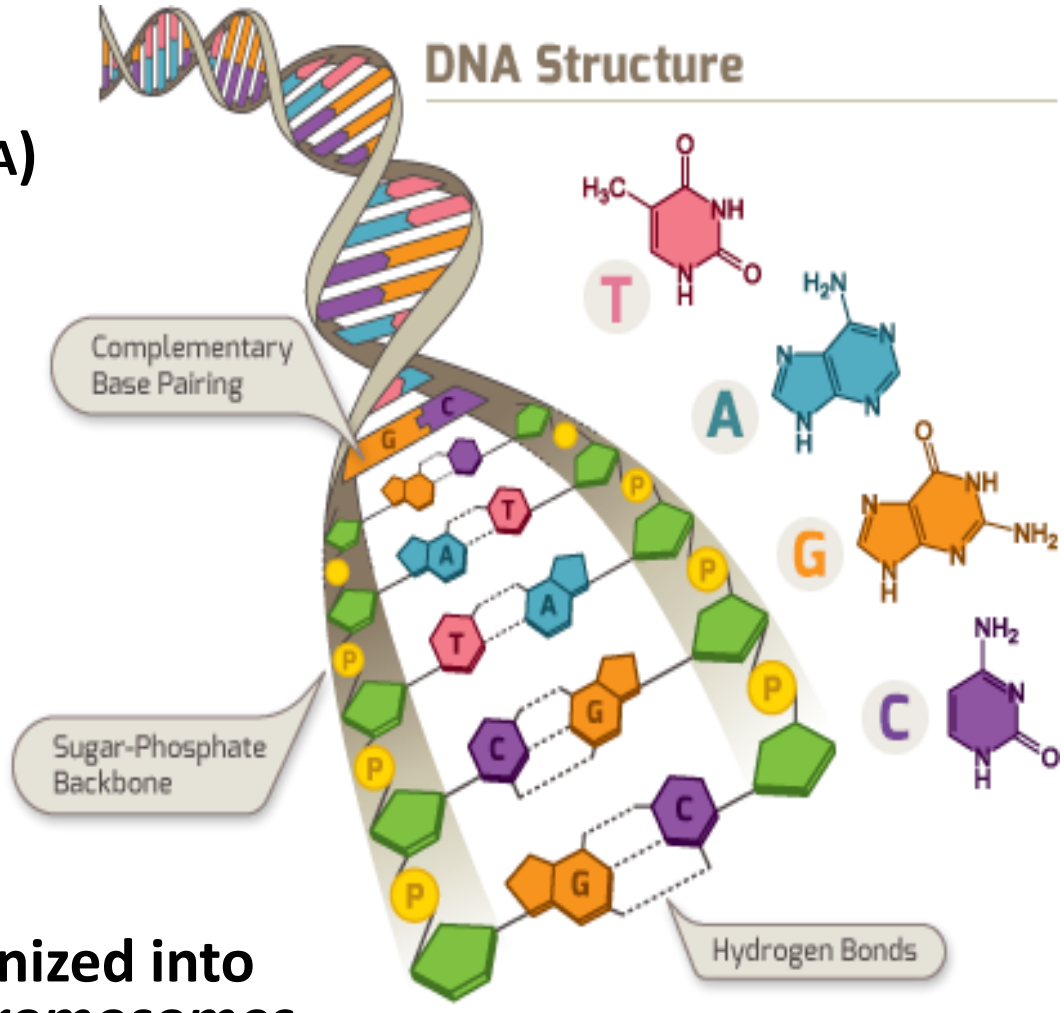
…1943: Avery-MacLeod-McCarty experiment showed that DNA is the hereditary material in bacteria.

- In 1953, James Watson and Francis Crick suggested the double-helix model of DNA structure based on a single X-ray diffraction image.

DNA

DNA is a long polymer made from repeating units called nucleotides, or *bases*.

- **Four types of bases:**
  - **T - Thymine (Uracil in RNA)**
  - **A - Adenine**
  - **G - Guanine**
  - **C - Cytosine**
- **In living organisms DNA does not usually exist as a single molecule, but instead as a pair of molecules that are held tightly together, entwined in the shape of a double helix.**
- **Within cells, DNA is organized into long structures called *chromosomes*.**



Genome and Genetic Code

What is Genome?

- Genetic material of an organism, essentially the instructions on making proteins and RNAs.
- Inscribed in DNA: complete DNA sequence.
- Includes both the *genes* and the non-coding regions.

What is Gene?

- The portion of the genome that codes for a single protein or an RNA.
- The molecular unit of heredity of a living organism.
- The size of a single gene may vary greatly, ranging from ~1,000 bases to ~1 million bases in humans.

What is Genetic Code?

- The set of rules by which information encoded within DNA or RNA is translated into proteins.
- In general, the genetic code specifies 20 standard amino acids by means of triple nucleotide *codons* and is basically the same for all organisms on Earth.

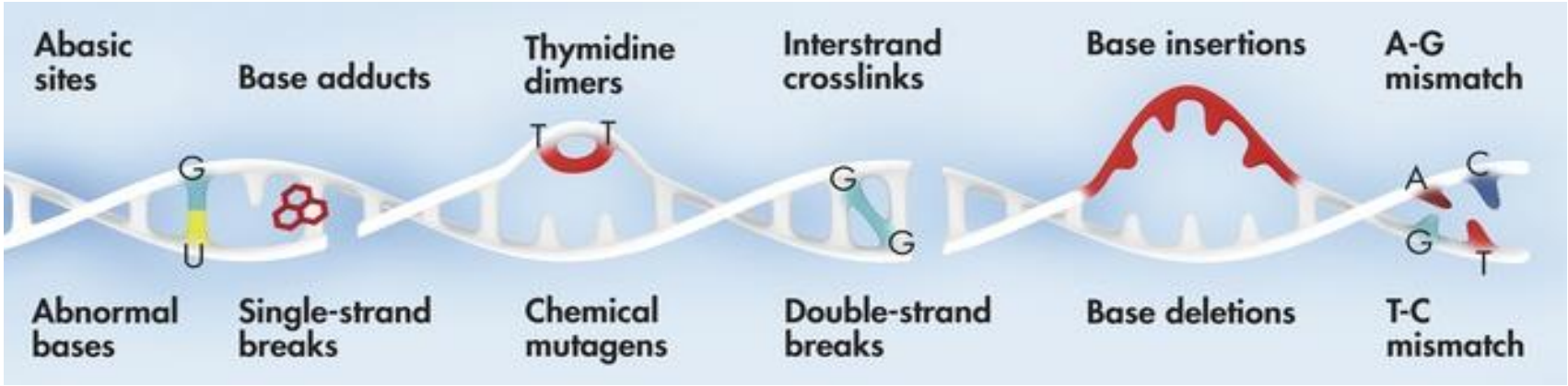
Human DNA

- The Human Genome Project (1990-2003) produced the first complete sequences of individual human genomes.
- Human genome contains ~3 billion bases and ~20,500 genes.
- Over 98% of the human DNA comprises non-coding repetitive sequences (the role, functions and descriptions of these sequences are currently being investigated by scientists).

- By 2012, thousands of human genomes have been completely sequenced.
- All humans have the DNA that is 99.9% similar, however the rest 0.01% is enough to identify different individual DNA sequences (*i.e. tell apart which DNA belongs to whom*).
- Primary (and now standard routine!) applications include paternity testing as well as DNA profiling in criminal investigations.

DNA Damage

DNA is damaged up to 1 million times per cell per day.



- **The cells have an elaborate type-of-damage-specific system of DNA repair that is constantly active.**
- **A cell that has accumulated a large amount of DNA damage, or one that no longer effectively repairs damage incurred to its DNA, can enter one of three possible states:**

1. **an irreversible state of dormancy, known as *senescence***
2. **cell suicide (*apoptosis*) or programmed cell death**
3. **unregulated cell division, which can lead to cancer**

DNA Mutations

A mutation is a permanent change in the DNA sequence.

- **Mutations can be:**
  - ***spontaneous*** **(by chance)**
  - ***induced*** **by mutagens (physical, chemical or biological agents)**

- **Factors that cause mutations:**
  - **external - environmental factors such as sunlight, radiation, and smoking**
  - **native - errors during DNA replication**

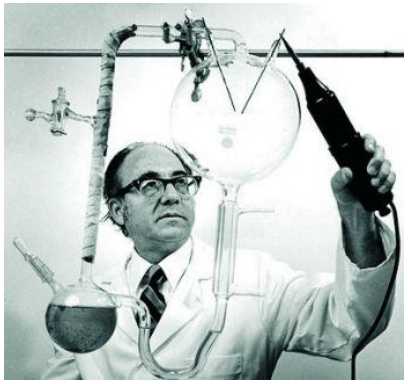
- **Mutations can lead to:**
  - **an *evolutionary advantage* of a certain genotype**
  - **disease, developmental delays, structural abnormalities, or other negative effects.**

Example: Sickle cell anemia is a disorder in which the body makes sickle-shaped red blood cells as a result of DNA mutation.

DNA Half-Life

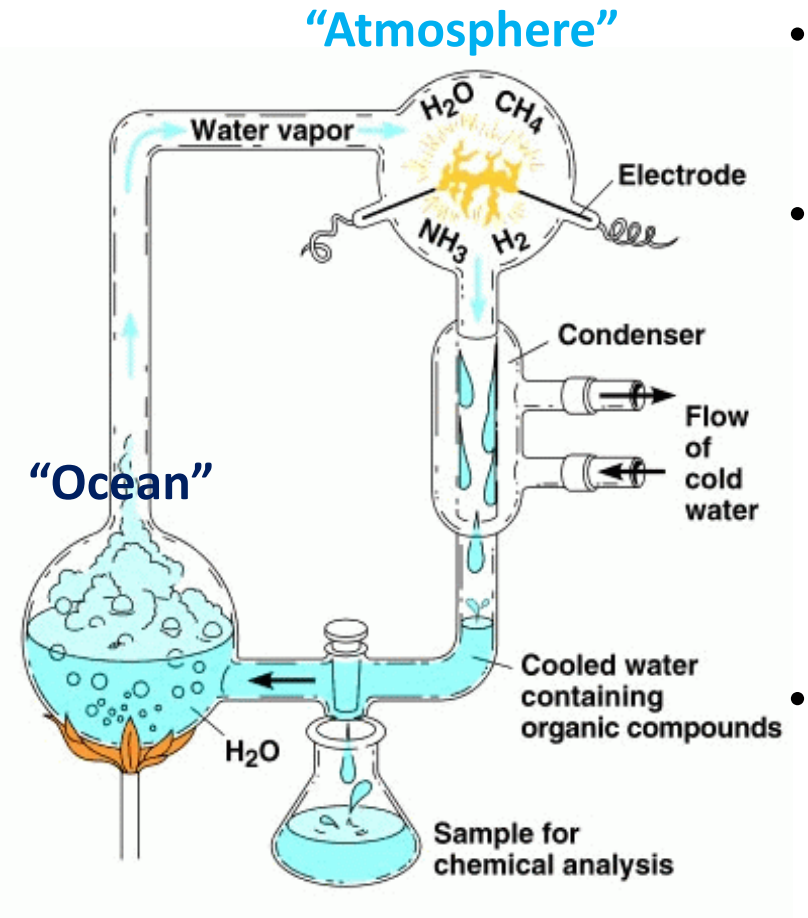
In 2012, researchers have calculated that DNA from bones has a 521 year half-life, which means that the oldest clone-able samples of DNA could be no more than 2 million years old.

This result rules out any possibility of ever replicating dinosaurs, as the youngest dinosaurs were around more than 65 million years ago…



Miller–Urey experiment, 1953: chemical origins of life

Stanley L. Miller Harold C. Urey



- **Test for the occurrence of chemical origins of life by simulating the conditions thought at the time to be present on the early Earth.**
- **The experiment used water (H_2O), methane (CH_4), ammonia (NH_3), and hydrogen (H_2) all sealed inside a sterile loop array of glass flasks; one flask was half-full of liquid water ("ocean") and another flask contained a pair of electrodes. The liquid water was heated to induce evaporation, sparks were fired between the electrodes to simulate "lightning through the atmosphere" and water vapor; then water could "precipitate" that is condense and trickle back into the first flask in a continuous cycle.**
- **After two weeks: 10–15% of the carbon was now in the form of organic compounds; >20 amino acids formed; sugars were also formed. However, *nucleic acids were not formed* within the reaction…**