or brain cells) differ only because they **express**, or actually use, different portions of their full set of genes.

- Therefore the DNA found in almost any cell in any organism contains the complete instructions for building an organism of that species. This fact underlines the science of cloning.

- A strand of DNA contains a long, unbroken sequence of DNA bases. The set of rules for reading DNA is called the **genetic code**.
  - **Genetic "words"** consist of three DNA bases in a row. For the purpose of protein building, each word represents either a particular amino acid or a "start reading" or "stop reading" instruction.
    - The total number of words in the genetic code is **64** (four DNA bases to choose from and genetic words are composed of three DNA bases in a row).
  - Most organisms only use 20 amino acids to make proteins (out of a possible 64 genetic words), so there is a fair amount of redundancy in the genetic code.
    - The codes for most amino acids really depend on just the first two bases in the three-base genetic words. This suggests that the genetic code once depended only on two-base words instead of three-base words.
    - Most biologists now believe that early life-forms used only a two-base language, which later evolved into the current three-base language of the genetic code.
  - Another important feature of the genetic code is that it is the same in nearly all living organisms on Earth. Only a few organisms show any variation in this code and these variations are minor.
    - This common language of the genetic code is further evidence for a common ancestor of all life on Earth.
- **The role of RNA**: many enzymes are involved in carrying out genetic instructions, and the molecule RNA plays a particularly important role in these functions.
  - A molecule of RNA is quite similar in structure to a single strand of DNA, except that it has a slightly different backbone and one of its four bases is different from one of the DNA bases.
    - RNA uses a base called **uracil (U)** in place of DNA's thymine (T).
  - Several different types of RNA participate in carrying out genetic instructions in the cell. These different types of RNA work together to attach the amino acids into the chains that make proteins:
    - **Messenger RNA (mRNA)**: transcribes the DNA instructions for use in another part of the cell.
    - **Ribosomal RNA (rRNA)**: molecules that compose the ribosome within a cell, where amino acids are assembled into proteins.
    - **Transfer RNA (tRNA):** molecules that collect individual amino acids from within the cell and bring these to the ribosome.
  - The process described above is known as **RNA translation**, because it effectively translates the genetic instructions into an actual protein.
- **How does life evolve?** Our current knowledge of DNA has allowed us to further confirm Darwin's theory of evolution by natural selection, since we now know how such variation occurs on the molecular level.
  - The key to this knowledge lies in understanding how DNA molecules gradually change through time.

    - These discoveries led biologists to envision that modern, DNA-based life may have arisen from an earlier **RNA world**, in which RNA molecules served both as genes and as chemical catalysts for copying and expressing those genes.
- To create this RNA world, experiments were created to show that several types of inorganic molecules (such as **mineral clay**) can facilitate the self-assembly of long, complex organic molecules.
    - Other experiments show that RNA, along with other organic molecules and tiny bits of mineral clay, could easily have become confined within naturally forming microscopic enclosures often called **"pre-cells" (or vesicles).**
        - **Pre-cells can be formed naturally in at least 2 different ways**: **(1)** by cooling a warm-water solution of amino acids so that they form bonds among themselves to make an enclosed spherical structure or **(2)** by mixing lipids with water.
    - Experiments show that lipid pre-cells can form on the surface of the same clay minerals that help assemble RNA molecules, sometimes with RNA inside them.
- Confining RNA and other organic molecules within pre-cells could have facilitated an origin of life in two important ways:
    - **(1)** Keeping **molecules concentrated and close together should have increased the rate of reactions** among them, making it far more likely that a self-replicating RNA would have arisen.
        - The high rate of reactions would also have greatly increased the probability that cooperative relationships between RNA molecules and proteins could arise.
    - **(2)** Once self-replicating RNA molecules came to exist, **pre-cells would have kept them isolated from the outside** in a way that should have facilitated a molecular analog to natural selection, in which RNA molecules that replicated faster and more accurately would rapidly come to dominate the population.

Solar System

The Big Picture, pg. 256

- The general requirements for life are much broader than the requirements for complex beings such as humans. We would count a world as habitable if any form of life could survive on it, even if the life were microscopic.
- Our solar system contains a vast number of worlds, but most of them are unlikely to have life because they lack a liquid medium of any kind. Nevertheless, a few worlds may meet the criteria for habitability in at least some regions of their surfaces, subsurface, or atmospheres. More worlds may have had liquid water or other liquids in the distant past.
- Much of our current knowledge about the solar system and the potential for life comes from studies conducted by robotic spacecraft. We are living during a time when many spacecraft are simultaneously exploring different worlds in our solar system, and more missions are being planned for the future.