DNA Structure and Replication

- Genetic Material Must Exhibit Four Characteristics
  - •replicate
  - •store information
  - •express information
  - •allow variation by mutation.
- Up to 1940's, proteins and nucleic acids were the major candidates for the genetic material.
  - For a long time, protein was favored to be the genetic material.
    - –It is abundant in cells,
    - –It was the subject of the most genetic research
    - –DNA was thought to be too simple to be the genetic material
  - Evidence Favoring DNA as the Genetic Material Was First Obtained during the Study of Bacteria and Bacteria's Viruses (Bacteriophages)
    - Transformation
      - Griffith showed that non-deadly strains of bacteria could be transformed into deadly forms.
      - speculated that the transforming principle could be part of the polysaccharide capsule or some compound required for capsule synthesis.
      - Frederick Griffiths was a bacteriologist studying pneumonia
      - He discovered two types of bacteria:
        - Smooth colonies
        - Rough colonies
      - When heat was applied to the deadly smooth type…And injected into a mouse…The mouse lived!
      - Griffith injected the **heat-killed** type and the **non-deadly** rough type of bacteria.
      - The bacteria "transformed" itself from the heated non-deadly type to the deadly type.
    - Avery, et al. demonstrated that transformation was caused by DNA and not protein.
      - Repeated Griffith's Experiment but with enzymes
    - Hershey and Chase demonstrated that DNA, and not protein, enters bacteria during bacteriophage infection.
      - The Hershey-Chase results reinforced the Avery, McCarty, and MacLeod conclusion:
      - DNA carries the genetic code!
- Structure
  - Nucleotides are the building blocks of DNA. They consist of a nitrogenous base, a sugar, and a phosphate.
    - The nitrogenous bases can be:
      - Purines –adenine (A) and guanine (G).
      - Pyrimidines –cytosine (C), thymine (T), and uracil (U).
      - DNA has A, C, G, and T
      - RNA has A, C, G, and U.
    - Sugar
      - RNA contains ribose;
      - DNA contains deoxyribose.
  - Nucleotides are linked by a phosphodiester bond between the phosphate group at the C-5' position and the OH group on the C-3' position.
  - Chargaff showed that the amount of A is proportional to T and the amount of C is proportional to G.
  - Rosalind Franklin's X-ray diffraction of DNA showed a helical structure.
  - Watson and Crick proposed DNA is a double helix in which the two strands are antiparallel and the bases are stacked on one another.
    - The two strands are connected by A-T and G-C base pairing.

        - A-T base pairs form two hydrogen bonds and G-C base pairs form three hydrogen bonds.
- Semiconservative Replication
    - The complementarity of DNA strands allows each strand to serve as a template for the other.
        - 1. Unraveling and Separating
            - Helicases unwind and hold apart DNA.
            - Starts at an initiation site.
        - 2. Add new parts
            - RNA primer attaches on.
            - Attracts DNA polymerase which binds free nucleotides to the template strand.
            - Ligases join backbone bonds
            - Multiple origins of replication allow the genome to be replicated in a few hours.
        - 3. Discontinuous Replication
            - Replication occurs in a 5' to 3' direction.
            - As the replication fork moves, only one strand can serve as a template for continuous DNA synthesis. This is the leading strand.
            - The lagging strand is synthesized as Okazaki fragments.
    - DNA Repair
        - 1 in a million incorrect base matches.
        - Group of 50+ molecules that find mistakes, remove them, and replace with new DNA.

Transcription

- DNA -> RNA – DNA is copied into RNA
- Occurs in the nucleus
- The Structure of RNA Is Similar to DNA
    - RNA is single stranded
    - In RNA, the sugar ribose replaces deoxyribose of DNA and uracil replaces thymine.
- There are three kinds of RNAs: messenger RNA (mRNA), ribosomal RNA (rRNA), and transfer RNA (tRNA).
    - All RNAs originate as complementary copies of one of the strands of DNA.
    - DNA serves as the template for their synthesis.
    - rRNAs are components of ribosomes for protein synthesis,
    - mRNAs are the template for protein synthesis,
    - tRNAs taxi amino acids during protein synthesis.
- Control of Transcription
    - turning on and off of genes
    - example – Lac Operon
- Process of Transcription
    - 1. Enzymes unwind the double helix.
    - 2. RNA polymerase binds onto promoter region.
    - 3. RNA polymerase matches complementary bases to that of DNA in a 3' to 5' direction
    - 4. A certain sequence of the DNA terminates the RNA encoding.
    - 5. RNA breaks off and the helix coils back together
- The DNA strand that is transcribed from is called the coding strand.
- Messenger RNA Processing
    - Capping
        - During transcription, short sequences cap the 5' end.
        - 100-200 adenines are added to the 3' end
        - This tells the cell to export it from the nucleus.
    - RNA Splicing
        - Noncoding regions of genes are introns
        - Coding regions are called exons.
        - Introns are transcribed, but then cut out. The other parts are spliced back together.
        - Introns = 95% of our 3 billion bases

Translation

- RNA -> Protein – RNA is copied into Protein
- makes chains of amino acids
- Occurs in the cytoplasm at a ribosome
- RNA Review
  - rRNAs are components of ribosomes for protein synthesis,
  - mRNAs are the template for protein synthesis,
  - tRNAs taxi amino acids during protein synthesis.
- In the mRNA, triplet codons specify one amino acid.
  - The code contains “start” and “stop” codons.
  - The triplet code provides 64 codons to specify the 20 amino acids.
  - Many amino acids are specified by more than one codon. Only tryptophan and methionine are encoded by a single codon.
  - tRNAs match triplet codons with an amino acid.
  - Has an anticodon that base-pairs with the codon in the mRNA.
- Ribosomes consist of proteins and rRNAs and have a large subunit and a small subunit.
- Translation Can Be Divided into Three Steps
  - Initiation requires the small and large ribosomal subunits and a tRNA with Met to bind onto the mRNA.
  - Termination is signaled by a stop codon (UAG, UAA, UGA) in the A site.
  - Protein and last tRNA break apart, then rRNA subunits break off.
  - Several sites are translated at once
- Wobble
  - The bonding between the codon and anticodon at the third position is not always based on correct base pairings.
  - Allows for quick pairings
- One gene = One protein
  - Bacteria and Hemoglobin studies proved theory.
- Protein Structure Is the Basis of Biological Diversity
  - Following translation, polypeptides fold up and assume higher order structures, and then they may interact with other polypeptides.
  - Amino Acids have the same basic structure with a radical group that changes its properties.
  - There are four levels of protein structure: primary, secondary, tertiary, and quaternary.
  - Protein Function Is Directly Related to its Structure
  - Proteins play diverse roles in the body. Hemoglobin binds to and transports oxygen.
    - Collagen and keratin are structural proteins. Actin and myosin are contractile proteins, found in muscle tissue.
    - Other examples are the immunoglobulins, which function in the immune system of vertebrates; transport proteins, involved in movement of molecules across membranes; some of the hormones and their receptors, which regulate various types of chemical activity; and histones, which bind to DNA in eukaryotic organisms.
    - Enzymes, the largest group of proteins, are involved in biological catalysis, a process whereby the energy of activation for a given reaction is lowered.