Genetics and Cellular Function

- Genes and nucleic acids
- Protein synthesis and secretion
- DNA replication and the cell cycle
- Chromosomes and heredity

Organization of the Chromatin

- Threadlike chromatin = chromosomes = 46 DNA molecules and associated proteins
- Nondividing state = DNA molecules compacted
  - coiled around core particle (histone protein)
  - zig-zagged, looped and coiled onto itself
- Preparing to divide
  - DNA copies itself to form 2 parallel sister chromatids

Nucleotide Structure

- DNA = polymer of nucleotides
- Each nucleotide consist of
  - phosphate group
  - sugar
    - ribose (RNA)
    - deoxyribose (DNA)
  - nitrogenous base
    - in this picture = adenine

Nitrogenous Bases

- Purines - double ring
  - guanine
  - adenine
- Pyrimidines - single ring
  - uracil - RNA only
  - thymine - DNA only
  - cytosine – both
- DNA bases =CTAG
- RNA bases = CUAG

Complementary Base Pairing

- Nitrogenous bases united by hydrogen bonds
- DNA base pairings
  - A-T and C-G
- Law of complementary base pairing
  - one strand determines base sequence of other

DNA Function

- Code for protein synthesis
- Gene - sequence of DNA nucleotides that codes for one protein
- Genome - all the genes of one person
  - humans have estimated 30-35,000 genes
  - other 98% of DNA noncoding – “junk” or regulatory

RNA: Structure and Function

- RNA smaller than DNA (fewer bases)
  - transfer RNA (tRNA) 70 - 90 bases
  - messenger RNA (mRNA) over 10,000 bases
  - DNA has over a billion base pairs
- Only one nucleotide chain (not a helix)
  - ribose replaces deoxyribose as the sugar
  - uracil replaces thymine as a nitrogenous base
- Essential function
  - interpret DNA code
  - direct protein synthesis in the cytoplasm

Genetic Control of Cell Action through Protein Synthesis

- DNA directs the synthesis of all cell proteins
  - including enzymes that direct the synthesis of nonproteins
- Different cells synthesize different proteins
  - dependent upon differing gene activation

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Preview of Protein Synthesis

- **Transcription**
  - **messenger RNA (mRNA) is formed next to an activated gene**
  - **mRNA migrates to cytoplasm**
- **Translation**
  - **mRNA code is "read" by ribosomal RNA as amino acids are assembled into a protein molecule**
  - **transfer RNA delivers the amino acids to the ribosome**

Genetic Code

- **System that enables the 4 nucleotides (A,T,G,C) to code for the 20 amino acids**
- **Base triplet:**
  - **found on DNA molecule (ex. TAC)**
  - **nucleotides that stand for 1 amino acid**
- **Codon:**
  - **"mirror-image" sequence of nucleotides found in mRNA (ex AUG)**
  - **64 possible codons (4^3)**
    - **often 2-3 codons represent the same amino acid**
    - **start codon = AUG**
    - **3 stop codons = UAG, UGA, UAA**

Transcription

- **Copying instructions from DNA to RNA**
  - **RNA polymerase binds to DNA**
    - **at site selected by chemical messengers from cytoplasm**
  - **opens DNA helix and transcribes bases from 1 strand of DNA into pre-mRNA**
    - **if C on DNA, G is added to mRNA**
    - **if A on DNA, U is added to mRNA, etc.**
  - **rewinds DNA helix**
- **Pre-mRNA is unfinished**
  - **"nonsense" (introns) removed by enzymes**
  - **"sense" (exons) reconnected and exit nucleus**

Alternative Splicing of mRNA

- One gene can code for more than one protein
- Exons can be spliced together into a variety of different mRNAs.

Translation of mRNA

- mRNA begins with leader sequence
  - binding site for ribosome
- Start codon AUG

Steps in Translation of mRNA

- Growth of polypeptide chain
  - next codon read, next tRNA attached, amino acids joined, first tRNA released, process repeats and repeats
- Stop codon reached and process halted
  - polypeptide released and ribosome dissociates into 2 subunits

Transfer RNA (tRNA)

- Activation by ATP binds specific amino acid and provides necessary energy to join amino acid to growing protein molecule
- Anticodon binds to complementary codon of mRNA

Polyribosomes and Signal Peptides

- Polyribosome
  - cluster of 10-20 ribosomes reading mRNA at one time
  - horizontal filament - mRNA
  - large granules - ribosomes
  - beadlike chains projecting out - newly formed proteins
    - takes 20 seconds to assemble protein of 400 amino acids
    - cell may produce > 150,000 proteins/second
- Signal peptide = beginning of chain of amino acids
  - determines protein's destination within cell

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Chaperones and Protein Structure

- **Newly forming protein molecules must coil or fold into proper 2nd and tertiary molecular structure**
- **Chaperone proteins**
  - **prevent premature folding, assist in proper folding and escort protein to final destination**
- **Stress or heat-shock proteins**
  - **produced in response to heat or stress**
  - **help damaged protein fold back into correct functional shapes**

Errors and Mutations

- **Error rates of DNA polymerase**
  - **in bacteria, 3 errors per 100,000 bases copied**
- **Proofreading and error correction**
  - **a small polymerase proofreads each new DNA strand and makes corrections**
  - **results in only 1 error per 1,000,000,000 bases copied**
- **Mutations - changes in DNA structure due to replication errors or environmental factors**
  - **some cause no effect, some kill cell, turn it cancerous or cause genetic defects in future generations**