Biology 05.1

Genetics

"My frame was not hidden from Thee, when I was being formed in secret and intricately and curiously wrought in the lowest parts of the earth." Psalms 139:15

Genetics

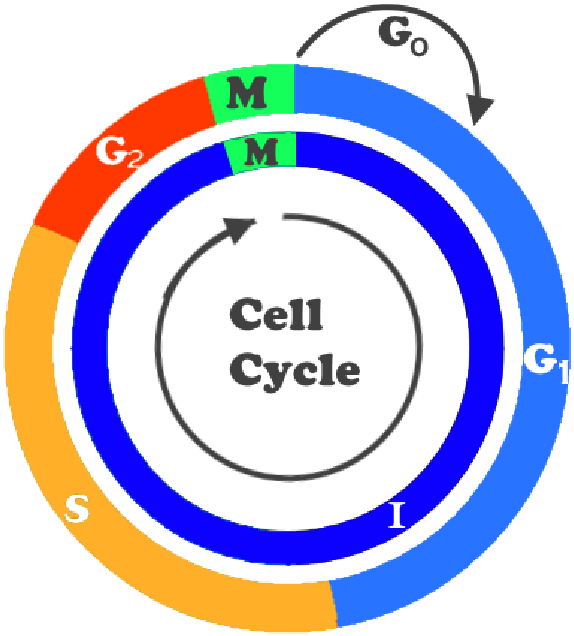
1. Genetics is the study of the code of life, heredity, and variations of the code.
2. Heredity is the transferring of molecularly encoded genetic information from parents to progeny.
3. Progeny (offspring) inherit the chemical code for their traits from their parents.
4. Every living organism possesses genetic information and a mechanism to propagate that information.
5. Every cell in an organism's body possesses all the genetic information to clone itself.
6. Genetic information is stored in the DNA molecule.
7. Many organisms have more than one DNA molecule of genetic information. Humans have 46.
8. Each DNA molecule in the nucleus of a cell is called a chromosome.
9. All of the DNA, RNA, and associated proteins in the nucleus of a cell is called chromatin.
10. Nucleotides > DNA > Genes > chromosomes > chromatin
11. A complete set of genetic information in the nucleus of a cell is called the genome.
12. Genetic information is determined by the sequence of nucleotides in DNA.
13. Genes are segments of DNA nucleotide sequences that code for a particular protein.
14. Thousands of genes are located on a chromosome.
15. Mitochondria possess their own DNA and are inherited from the mother only.
16. Law of biogenesis: Kind produces kind.

Replicating the DNA molecule

1. Propagation of cells and organisms requires replicating the genetic code in the DNA molecule(s) to produce progeny.
2. DNA is replicated by a **semiconservative process** in which each parental DNA strand serves as a template for the synthesis of a new complementary daughter strand.
3. A coordination of several enzymes is required for the replicating of DNA.
4. Three enzymatically catalyzed and coordinated steps are involved: 1) initiation, 2) elongation and 3) termination.
5. Initiator proteins initiate replication at origin sites on the DNA by coordinating a complex of proteins to unzip the double-stranded DNA.
6. Helicase is the enzyme that unzips of DNA strands to form a replication fork.
7. Replication of DNA is unidirectional; 5' to 3'.
    a. One strand is copied continuously (leading strand), and the other as small pieces (Okazaki fragments form lagging strand).
    b. DNA ligase fuses the Okazaki fragments together.
8. DNA is elongated with a primer sequence of complementary RNA nucleotides, which are then replaced by DNA nucleotides.
9. Termination takes place when the primers are removed, replaced with new DNA nucleotides, and the backbone is sealed by DNA ligase.
10. DNA polymerase catalyzes the reactions to create a new chain of nucleotides for DNA replication.
11. Polymerase chain reaction (PCR) is used to replicate DNA *in vitro*.

Cell cycle

1. Replicating cells reproduce themselves asexually.
2. Replicating cells progress through a repetitive life cycle of two phases: 1) interphase and 2) M phase.



3. Interphase (I phase) has three stages.
   a. During the G1 stage or Growth stage 1 of the cycle, cells grow in size and duplicate organelles and cell structures like the centrosome (2 perpendicular centrioles).
   b. During S stage or Synthesis stage, DNA is replicated resulting into sister chromatids at centromere.
   c. During the G2 stage or Pre-mitotic phase 2, cells synthesize enzymes and components required for mitosis and cytokinesis.
   d. Cells that stop dividing continue to metabolize in G0 stage.
4. M phase (Mitosis)
   a. Prophase: Chromosomes condense, nuclear membrane dissolves, centrosome (2 perpendicular centrioles) divides and migrate, spindle fibers form.
   b. Metaphase: Sister chromatids line up at equatorial plate.
   c. Anaphase: Sister chromatids separate and are now called daughter chromosomes.
   d. Telophase: chromosomes uncoil, nuclear envelope forms, spindle fibers disappear, and then cytoplasm divides (Cytokinesis). The result is cloned cells.

Genes and Chromosomes

1. The length of all 46 human chromosomes from <u>one cell</u> measures about <u>7.2 feet</u>. This is derived by multiplying the length of a base pair (0.34nm) with the total number of base pairs (6.4 billion base pairs in 46 chromosomes) in human cells which equals 2.2 billion nm, which is 2.2 meters or 7.2 feet.
2. The length of <u>all 46 chromosomes</u> from all 37 trillion cells in the average human body is over 50 billion miles long. The moon is 238,900 miles from earth, and the sun is 93 million miles from

earth. Pluto is about 40 times further from the sun than earth at 3.8 billion miles. DNA in the human body will stretch from the sun to Pluto and back over 6.5 times!

3. All of the DNA collected from all of your body cells would fit in a one-inch cube.
4. About 142-150 nucleotide base pairs are wrapped around an octamer complex.
5. Each chromosome is a DNA molecule coated with protein.
6. Proteins provide protection and support for the chromosomes.
7. Proteins also aid in replication and transcription of DNA.
8. A hierarchy of genes exist (protein, iris, schlera, eye).
9. Carries information equal to 1,000 books each 600 pages thick.
10. The DNA molecule carries many different genes.
11. DNA structure was discovered by Watson and Crick in 1953.

Genetic similarities and differences

1. All organisms possess DNA based genetic information consisting of the same nucleotides.
2. Species characteristics: traits shared by members of the same species.
3. Individual characteristics: traits that make individuals different.
4. Unless you are an identical twin, your DNA is unique.
5. Fingerprints are unique to each person, even identical twins.
6. James Watson is the first person to have his genome sequenced. It was presented to him in a ceremony in Houston by Richard A. Gibbs, director of the Human Genome Sequencing Center at the Baylor College of Medicine in 2007 by the Human Genome Project on DVDs. A composite of anonymous donors from Buffalo was sequenced in 2003.
7. There are 3.2 billion base pairs in the human genome of 23 chromosomes.
8. There are approximately 20,000 protein coding genes in a human genome.
9. 98% of Human DNA is non-protein coding (RNAs & important products). No longer considered “junk” DNA.
10. Two humans share as much as 99.9% of the same genetic material and differ in only 0.1% of it.
11. Genome size does not correspond to the complexity of life.
    a. Genome size is described as mass (picograms), number of chromosomes, number of genes, number of protein-coding genes, or number of paired bases.
12. Base pair number (mass) does not correspond to the complexity of life.
    a. One picograms (pg) is equivalent to approximately 1 billion base pairs.
    b. The mass of DNA in the genome of an organism is called <u>the C-value</u>.
    c. Humans have 3.2 billion base pairs (3.2 pg) in their genome of 23 chromosomes.
    d. *Paris japonica* (a Japanese flowering plant) has the largest genome of all organisms, as of October 2014, with 152.23 billion base pairs in 40 chromosomes.
    e. Among eucaryotes, marbled lungfish (*Protopterus aethiopicus*) has the largest genome of all vertebrates at 132.8 billion base pairs.
    f. *Pelagibacter ubique* has the smallest known genome (1.3 <u>million</u> base pairs paired bases).
    g. The great variation between genome sizes among eucaryotes is called the <u>C-value paradox</u>.
13. Number of genes does not correspond to the complexity of life.
    a. The near-microscopic, freshwater crustacean *Daphnia pulex* has about 31,000 protein coding genes.
    b. Trichomoniasis, a single-celled protozoan, has the largest known number of genes among all organisms at 60,000.
    c. *Candidatus Hodgkinia cicadicola Dsem* has the smallest known number of genes 182 genes coding for protein.
    d. 20,000 protein coding genes make up 2% of the human genome. The rest of DNA is non-coding.

14. Chromosome number does not correspond to the complexity of life.
    a. Species sharing same number of chromosomes (46) as humans
        i. The barking deer (*Muntiacus reevesi*).
        ii. A vole (*Microtus arvalis*)
        iii. The zebra (*Equus grevyi*)
        iv. The bent wing bat (*Minopterus schreibersii*)
    b. A fern (*Ophioglossum reticulatum*) has 1,260 chromosomes, the largest number of all organisms.
    c. A butterfly (*Agrodiaetus shahrami*) has the largest number of chromosomes (268) among animals.
    d. The South American red viscacha rat (*Tympanoctomys barrerae*) has the largest number of chromosomes (102) among mammals.
    e. The Jack jumper ant (*Myrmecia pilosula*) has the fewest chromosomes of all multicellular organisms: females have 2 chromosomes, and males have 1.
    f. A single cell protist *(Oxytricha trifallax)* is capable of breaking its DNA into hundreds of thousand pieces (225,000), then reassemble the pieces.
    g. The largest animal (blue whale) has 44 chromosomes.
15. Humans possess similar DNA sequences (homologous segments) with other species.
    a. 97.5% of mouse chromosome 16
    b. 89% to 96% with chimpanzees (Varki A, Altheide TK (Dec 2005). "Comparing the human and chimpanzee genomes: searching for needles in a haystack.". *Genome Research* **15** (12): 1746–58).
    c. Cats 90%
    d. Dogs 82%
    e. Cows 80%
    f. Harbor seal genome 79% similar to human genome.
    g. Fruit fly 60%
    h. Chicken 60%
    i. Banana 50%
    j. 21% with worms,
    k. 7% of genetic material in common with the *E. coli* bacteria,

Name	# chromosomes (2n)	# genes	# protein coding genes (1n)	mass (pg)	# base pairs
Candidatus Carsonella ruddii	1 circular (1n)	213	182	0.159,662	1.6×10^6
Pelagibacter ubique	1n	1389	1354		1.3×10^6
Myrmecia pilosula	2				
Macropus giganteus	16				
Daphnia pulex	24		31,907		200×10^6
Protopterus aethiopicus	28			132.8	132.8×10^9
Paris japonica	40			152.23	150×10^9
Homo sapien	46		25,000	3.5	3.5×10^9
Muntiacus reevesi	46				
Pan troglodytes	48				

Gorilla	48				
Beaver	48				
Lepus	48				
Bombyx mori	54				
Tympanoctomys barrerae	102				
Agrodiaetus shahrami	268				
Ophioglossum reticulatum	1,260				
Oxytricha trifallax	15,600	30,000			50 x 10^6

DNA similarity does not necessarily mean phenotypic similarity or ancestral relatedness.

1. All living cells have a great deal in common by design.
2. Genetic similarity is expected because they have the same Designer, they use the same nutrients (C, H, O, etc.), they make the same products (hormones, enzymes, membranes, etc.), and they use the same metabolic processes such as transcription, translation, replication, glycolysis, Kreb's cycle, electron transport, etc.
3. One Designer created all living organisms to use the same materials. Thus, many genes and products can be shared like sharing parts for cars, computers, and buildings.
4. Insects have shown Parkinson's symptoms when human gene inserted. Using insects revolutionizes research for human medicine.
5. There is a 6% difference between chimpanzees and humans when comparing entire genome rather than just substitutions in the base building blocks of genes.
6. 1% difference in the genetic code of humans is 320 million meaningful changes in base pairs.

Minimal gene set concept

1. The minimal gene set concept proposes that genomes can be reduced to a minimum number of essential genes.
2. The number of essential genes are different for different organisms.
   a. *Escherichia coli* requires 1,617 genes.
   b. *Streptococcus pneumoniae* requires 244 genes.
3. The first synthetic 'cell' was produced in 2010 in the J. Craig Venter Institute (JVCI) using the 1.08 million base pair chromosome of a modified *Mycoplasma mycoides*.
   a. Synthesized DNA was inserted into another species of Mycoplasma.
4. JVCI plans to create *Mycoplasma laboratorium* using synthesized DNA determined to be a minimal bacterial genome (from computer design to bacterial cell).
5. The most efficient genome known is in *Utricularia gibba* (a bladderwort plant) with only 3% noncoding DNA.
   a. Non-coding regions of DNA often repeat short segments of code thousands of times.
   b. Non-coding regions in gene are called introns. Non-coding regions external to a gene are called exons.
   c. Introns must be removed from mRNA and exons sliced together to form a mature mRNA that can be used to translate into protein.
6. Only 2 percent of the human genome contains information regarding the formation of proteins. All the rest are so called non-coding regions.

7. Only 10 percent or less of base pairs in bacteria and viruses appear to be unessential.
8. A minimal gene set for minimal metabolism necessary for cellular life defines the irreducible complexity point for living cells.

Living computers

1. Living cells operate like a computer. They execute a code.
2. Unlike a computer that can be switched on and off with a power button, cells originate from God who gives and sustains life.
3. Life requires continuity back to original creation. Life comes from life, which comes from God.
4. Once a cell dies, it cannot be revived.
5. A cell’s code can be preserved like a computer program.
6. Code can be deleted, added to, or modified.
7. Cellular code determines the biochemical pathways in a cell.
8. All living cells share genetic codes for biochemical pathways they have in common.
9. Genetic codes can be swapped between cells artificially or naturally.
10. New codes can be designed and created synthetically.
11. Code can be written to modify any nutrient and produce another.
12. Biochemical pathway charts show paths of cell metabolism required to make molecules.
13. Reverse engineering can lead to new genetic codes.
    a. Determine the desired end product.
    b. Determine the biochemical pathway to produce the end product.
    c. Determine the enzymes needed for the biochemical pathway.
    d. Determine the genetic code needed to make the enzymes.