A. Introduction
   a. Prokaryotes use binary fission to divide (Fig. 8.3)
   b. Eukaryotes use mitosis and meiosis
      i. Mitosis – growth, development, maintenance, repair. Also asexual reproduction in some organisms.
      ii. Meiosis – sex. Produces gametes (egg and sperm) (Fig. 8.13)
   c. Chromosome organization
      i. Condensation varies in cell cycle
      ii. Terms: chromosome, chromatid, centromere, telomere, homologs (Fig. 8.4)
      iii. Karyotype (Fig. 8.19)

B. The cell cycle (Fig. 8.5)
   a. G1 → S → G2 → M
   b. Interphase = G1, S, G2
   c. Checkpoints exist to regulate progression (Fig. 8.9). Cancer can occur if checkpoints are missing or ignored.
   d. Stages of mitosis (Fig. 8.6)
      i. Prophase – chromosomes condensed and attached to spindle fibers
      ii. Metaphase – chromosomes are lined up on equator (metaphase plate)
      iii. Anaphase – chromosomes are separating
      iv. Telophase – chromosomes at poles
   e. Cytokinesis – cells physically separate
      i. Animals – pinch off. Actin pinches. (Fig. 8.7)
      ii. Plants – build a cell plate. Vesicles transport materials to build wall.
   f. Show movies

C. Sexual reproduction (Fig. 8.13)
   a. Stages: meiosis I (homologs separate), meiosis II (sisters separate) (Fig. 8.14)
      i. Prophase I – crossing-over occurs between homologs. Mechanism (Fig. 8.18B).
      Chiasma is intermediate structure (Fig. 8.18A).
      ii. Metaphase II – pairs line up so that homologs separate.
   b. Compare mitosis and meiosis (Fig. 8.15)
   c. Degree of variation from sexual reproduction
      i. Shuffling of homologs: \(2^{23} = 8\) million
      ii. Fusion of gametes \(2^{23} \times 2^{23} = 64\) trillion
      iii. Crossing-over and mutations = near infinite

D. Alterations in Chromosome number
   a. Downs from Trisomy 21 (Fig. 8.20)
   b. Caused by nondisjunction (Fig. 8.21).
   c. Nondisjunction with sex chromosomes (Tab. 8.22)
   d. Other breakages (Fig. 8.24)
      i. Deletions – lose a piece
      ii. Duplications – copy a piece
      iii. Inversions – turn a piece around
      iv. Translocation – swap two pieces
Chapter 9 – Genetics

A. Gregor Mendel
   a. Experiments with peas
      i. Crossing peas (Fig. 9.2C)
      ii. Traits that he used (Fig. 9.2D)
      iii. Keeping track of generations (P, F1, F2 etc) (Fig. 9.3)
   b. Mendel’s Laws
      i. Law of Segregation – each allele will separate independently
      ii. Law of Independent assortment – each gene will segregate alleles independently of other genes.
   c. Vocabulary
      i. Gene (location of trait/alleles) and alleles (form of the gene)
      ii. Dominant (masking trait/allele) vs. recessive (masked trait/allele)
      iii. Homozygous (same alleles) vs. heterozygous (different alleles)
      iv. Phenotype (trait) vs. genotype (genetic make up)
   d. Punnett Squares are tools for calculating probability of crosses (Fig. 9.3B, 9.7)

B. Single Trait Crosses
   a. E.g. AA X aa
   b. Monohybrid cross – Aa X Aa
   c. Test cross – cross a dominant to the recessive to figure out genotype (Fig. 9.6)

C. Two trait crosses
   a. AABB X aabb
   b. Dihybrid cross – AaBb X AaBb (Fig. 9.5)

D. Pedigree Analysis
   a. Dominant and recessive disorders (Fig. 9.8b)

E. Non-Mendelian traits
   a. Incomplete dominance – heterozygous has a new trait (pink flowers) (Fig. 9.11a)
   b. Multiple alleles – more than two e.g. blood typing: use I^A, I^B, I (Fig. 9.12)
   c. Pleiotrophy – one gene controls more than one trait. e.g sickle cell (Fig. 9.13)
   d. Polygenic inheritance – multiple genes controlling one trait (Fig. 9.14)
   e. Linkage: genes close on same chromosomes.
      i. Normal chromosomal inheritance (Fig. 9.16).
      ii. Two genes close together (Fig. 9.17)
      iii. Sex-linked – gene is on the X or Y chromosome
         1. X-linked genes (Fig. 9.21). Hemophilia and color blindness (Fig. 9.22).
            Do this cross: X^C X^c Y

Chapter 10 – Molecular Biology of the Gene

A. DNA Structure (Fig. 10.3d)
   b. Strands run opposite 5’ → 3’ (Fig. 10.5b)
   c. ATGC bases and complementary base pairing
   d. Double helix with bases forming hydrogen bonds.
   e. Watson/Crick 1953 solved structure. Rosalind Franklin provided key evidence (Fig. 10.3a)

B. Replication
   a. Free nucleotides polymerize (Fig. 10.4a)
   b. Replication begins at a replication bubble (Fig. 10.5a)
c. Enzymes
   i. Helicase unwinds DNA
   ii. DNA polymerase attaches nucleotides. Only 5’ → 3’
   iii. DNA ligase glues lagging strand

C. Central Dogma: DNA → RNA → Protein. Use processes: Transcription, Translation (Fig. 10.6a, 10.8b)
   a. RNA
      i. Uses AUGC
      ii. mRNA, rRNA, tRNA
   b. Genetic Code (Fig. 10.8a)
      i. Each triplet codes for one a.a.
      ii. 64 possibilities with 20 a.a., therefore redundancy
      iii. Note stop codons.
      iv. Practice translation of sequence

D. Transcription (Fig. 10.9)
   a. 3 steps, initiation, elongation, termination
   b. Initiation: RNA polymerase binds to promoter
   c. Elongation: Template strand is read and new RNA is made.
   d. Termination: the terminator is reached and ends process

E. Translation
   a. tRNA: one for each amino acid. Has anticodon that is complementary to mRNA and site to add the right amino acid (Fig. 10.11a).
   b. Ribosome is enzyme: has a small and large subunit.
   c. Initiation: small ribosome and first tRNA binds mRNA. Large subunit comes on top. (Fig. 10.13b)
   d. Elongation: new aa-tRNA comes in to empty site. Polymerization, shift of ribosome. Used tRNA exits. (Fig. 10.14)
   e. Termination: When hits stop codon, no tRNA available so complex falls apart.

F. Mutations (Fig. 10.16)
   a. Deletion – remove bases
   b. Insertion – insert bases
   c. Point mutation – base mismatch substitution.
      i. Silent – a.a. is unchanged
      ii. Missense – a.a. is changed. Can be harmful or neutral.
      iii. Nonsense – a.a. changed to stop.

Chapter 11 – Gene Expression and Cancer

A. Eukaryotic Gene Regulation (Fig. 11.9)
   a. Transcriptional regulation
      i. Chromosomal structure
         1. Opening up structure eases txn (Fig. 11.3)
         2. Barr body is condensed X chromosome. Calicos are heterozygous for color. (Fig. 11.4)
      ii. Regulatory proteins bind promoters (Fig. 11.5)
         1. Transcription factors, enhancers help
         2. Inhibitors, silencers help to inhibit
   b. Post-transcriptional regulation
      i. Splicing (Fig. 11.6)
ii. Nuclear export

c. Translational regulation
   i. mRNA stability
   ii. Initiation factors help ribosome to bind to mRNA

d. Post-translational
   i. Modifications – chemical additions and cleavage can change activity (Fig. 11.8)
   ii. Protein stability – degradation of protein to get rid of it.

B. Differentiation and Development
   a. Differentiation – cell specialization. Different cells require different gene expression (Fig. 11.2)
      i. Stem cells are undifferentiated (Fig. 11.17)
      ii. Differentiated plant cells can become undifferentiated. (Fig. 11.14)
      iii. Nuclear transplantation in cloning Dolly (Fig. 11.15).
   b. Development – process of embryonic growth and differentiation (Fig. 11.10)
      i. Maternal determinants in egg – follicle cells stimulate genes to localize “head” determinants.
      iii. Homeotic genes are the master controller of organ development. (Fig. 11.14)

C. Cancer
   a. Characteristics (Fig. 11.19)
      i. Cancers divide uncontrollably (overproliferation)
      ii. This can lead to invasiveness (break barriers), angiogenesis (blood vessel growth), metastasis (break off to colonize in different locations)
   b. Causes – mutations. Accumulation of mutations may bring you to next stage.
      i. Mutated genes in cancers
         1. Protooncogenes → oncogenes. Due to extra copies formed, movement, or mutation within gene (Fig. 11.18a)
            a. E.g. ras (Fig. 11.20a)
         2. Inactivate tumor suppressor genes. (Fig. 11.18b)
            a. E.g. p53 (Fig. 11.20b)
      ii. Carcinogens: agents that cause cancer. Examples are chemicals, radiation (x-ray and ultra violet light), and viruses. (Tab 11.21)
   c. Treatments
      i. Chemo and radiation are too nonspecific – target any growing cell.
      ii. Specific drugs like Gleevec for leukemia block one specific protein (the oncogene abl).

Chapter 12 – Biotechnology

A. Recombinant DNA technology – genes mixed from different organisms.
   a. Plasmids are small circular DNA found in bacteria
   b. Restriction enzyme cloning (Fig. 12.1)
      i. Restriction enzymes cut DNA at specific sites (Fig. 12.2)
      ii. DNA ligase seals DNA back
   c. PCR – polymerase chain reaction
      i. Used to amplify DNA. Goes through rounds of DNA replication of a target sequence (Fig. 12.12)
      ii. Each cycle doubles amount of DNA made
   d. Gel electrophoresis
i. DNA fragments are separated by size into distinct bands (Fig. 12.13)
ii. DNA is negatively charged. It is forced through a gel matrix towards a positive electrode. Small fragments move faster.

B. Genomics
   b. DNA sequencing – the technology to decipher base sequence of DNA
   c. Human Genome Project
      i. Began by governments and completed by Celera (Craig Venter). Venter used an innovative approach (shotgun sequencing) that used computers to help complete the maps (Fig. 12.19).
      ii. Map of genome and some data (Fig. 12.18).
      iii. Comparison to other genomes (Tab 12.17)

C. Applications
   a. Drug factory – bacteria, yeast, plants and animals can be used to make human therapeutics
   b. Improve crops and livestock – disease resistance, increase yield (Fig. 12.8a)
   c. Gene therapy – cells removed from body, repaired, returned (Fig. 12.10)
   d. DNA profiling – creates a DNA fingerprint to identify individuals (fig. 12.11)
   e. Ethics
      i. Genetically modified products
         1. Safety of GM foods and environmental concerns.
         2. Intellectual property – ownership rights.
      ii. Screening and privacy issues
         1. Sickle cell screening caused discrimination in military.
         2. Knowledge by agencies: government and insurance companies
         3. Tay-Sachs screening helped reduce disease.
      iii. Inappropriate use
         1. Cloning humans.