Fundamentals

• Genes are DNA sequences that code for proteins
• Proteins catalyze reactions and make up structures
  – Thus genes indirectly control every reaction and structure making up a cell
• Genes are carried together on chromosomes

Other big difference between prokaryotic and eukaryotic DNA

• Eukaryotic genes are spread among multiple chromosomes.
• Almost all eukaryotic organisms are diploid at some stage in their life cycle.
  – This means that they have two copies of each chromosome - one from mom and one from dad.
• Thus they also have two copies of each gene.

Eukaryotic cell

1) Review of haploid, diploid, mitosis and meiosis (for relevant reading, see Campbell pp. 218-220 and 238-247)
2) Overview of sexual life cycles
3) Components of the eukaryotic cell
4) Overview of plant tissues

Prokaryotic Chromosomes and Cell Division

• Prokaryotic Genomes
  – Bacterial Chromosomes- Single strands of DNA
  – Reproduction- Binary Fission (asexual)

Eukaryotic Chromosomes and Cell Division

• Eukaryotic Genomes
  – Organization of Eukaryotic Genomes: Complexity!
    • Genomic size- each human cell has 3 meters of DNA!!
    • Chromosomal structure- Fold that 3 m into something manageable
      – Each Chromosome is one long strand of DNA
    • Biparental inheritance - diplody
The Cell Cycle

- Figure 7.6
  - Interphase- 90% of most cells life
    - Gap 1, Synthesis, Gap 2, and
  - Mitotic Phase
- What is Mitosis?

Cellular Division

- Three main functions of cell divisions
  - Reproduction
  - Growth and development
  - Tissue renewal

- Mitosis is a process of cell division that preserves chromosome number (e.g., diploid to diploid, haploid to haploid, or dikaryotic to dikaryotic) and results in genetically identical cells
  - Happens during a variety of processes, including simple growth, asexual reproduction
- Meiosis is the process of cell division whereby chromosome number is reduced by half (e.g. diploid to haploid)
  - Happens during sexual reproduction
  - Results in genetically variable haploid cells (usually spores or gametes)
Mitosis

- The process of cell division that results in the production of 2 daughter cells that are genetically identical to each other and to the parent cell from which they arose.
- Mitosis is for cell growth, development and repair
  - (and reproduction in single cell organisms)
- Occurs in Somatic Tissues

Parts of the Replicating Chromosome

Phases of Mitosis

Interphase
Prophase
Metaphase
Anaphase
Telophase
Genetic Variation

- Lets look around the class at our variation in Phenotype (how our genes are expressed on the outside)
- Lots of variation exists…why?
  - Helps with survival-
    - Hot Gene and Cold Gene...

Genetic Variation

- So variation is good for a population, how do we get it?
- Genetic Variation in Bacteria
  - Antibiotic resistance from random mutations

Genetic Variation

- Antibiotic Resistance
  - 1 in a million genes per generation will mutate
  - E. coli reproduces in 20 minutes (Generation Time)
  - $1 \times 2 \times 4 \times 8 \times 16 \times 32 \times 64 \times \ldots \ldots \ldots \ldots$,
    - $7$ hours = $1,000,000$ cells!!!
  - If one of these cells mutated so it was resistant, how many resistant cells in 7 more hours?

Genetic Variation

- So, for organisms with very short generation times, depending on mutations for genetic variation can be OK
- What is your generation time?
- Can’t depend on mutations for variation…too slow
- Why is there Sex?
  - Provides a way to mix genes and get variation
Meiosis

• The process of cell division that results in the production of 4 haploid gametes that are genetically different from one another and from the parents.
• In Mitosis we made exact copies of the parent cells, with two sets of chromosomes
• In Meiosis the result is different cells with only one set of chromosomes

Meiosis

• Gametogenesis - formation of the gametes
  – Sperm = Spermatogenesis
    • 1 cell = 4 sperm
  – Egg = Oogenesis
    • 1 cell = 1 egg + 3 polar bodies
  – Need to get Chromosome number in half!

Gametogenesis - formation of the gametes

Sperm = Spermatogenesis

• 1 cell = 4 sperm

Egg = Oogenesis

• 1 cell = 1 egg + 3 polar bodies

Need to get Chromosome number in half!
How do we get our Genetic Variation?

- **Random Assortment**
  - We have a set of chromosomes from mom and a set from dad, which of these gets into the gametes is random.
  - Four chromosome example: $2^2 = 4$ combos
  - Humans have 23 chromosomes: $2^{23} = \text{over 8 million different combos from each parent.}$
  - Over $64 \text{ trillion}$ different combinations of your parents genes!!

- **Crossing Over**
  - The exchange of corresponding segments between two homologous chromosomes.
  - Scrambles up the genes
  - Happens in Prophase I of Meiosis
  - Figure 7.18- example with one chromosome

How do we get our Genetic Variation?

- Extra Chromosomes
  - Down Syndrome
    - 3 copies of Chromosome 21
    - 1 in 700 births

When Meiosis Has Errors
Extra Chromosomes

When Meiosis Has Errors
- Abnormal Number of Sex Chromosomes

When Meiosis Has Errors
- Alteration of Chromosome Structure
  - Four main types of structural changes
  - Deletion, Duplication, Inversion, and Translocation

Errors are a source of Variation
- Most errors are "bad", but some can be good.
- New species can be developed from extra chromosome numbers (polyploid)
- Beneficial changes will persist, damaging ones will disappear
Polyploidy
• More than 2 sets of chromosomes (diploid)
• Very common in plants (50-60% of flowering plants!)
• Can occur as a result of non-disjunction during meiosis
• Can occur when cytokinesis fails (autopolyploidy)
• Can occur between two species-interspecific hybrid (autopolyploidy)
• Leads to reproductive failure (e.g. With diploids)
• Can lead to new species - especially sympatric speciation

Key points
• Mitosis results in production of genetically identical cells
  – Involved in growth, asexual reproduction
• Meiosis results in halving chromosome number, results in genetic variability
  – A key step in sexual reproduction

Eukaryotic cell
1) Review of haploid, diploid, mitosis and meiosis
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Reproduction
• Sex or no sex? Advantages and disadvantages
  • First eukaryotes were probably haploid and asexual. Sex gave rise to diploidy
  • polyploidy
  • Many plants (like many animals) can reproduce asexually
  • Alternation of generations
  • Gametophyte and sporophyte and the switch in dominance with advancement to land
  • Drought resistant spores, then seeds (complex multicellular structures in which reproductive structures are surrounded by sterile cells). Seeds have a special covering and stored food

Sex?
Sexual reproduction
• Introduce new genes
• Diversity in phenotype and genotype
• Resistance to disease
• Resistance to environmental change: Adaptation
• Hard to find a mate
• Picking the right one
• Mutations/problems
• Parental investment?
• Don’t know exactly what you get

Asexual reproduction
• Fast
• Know exactly what you get
• Can spread your exact genes
• Cover an area quickly
• No need to find a mate

Sex?
• No diversity (easily wiped out)
• Problem (if one exists) is reproduced
• Need a self recognition mechanism
Some can do both!

- **Combination** of sexual and asexual reproduction can bring the best of both worlds
- **Hermaphrodites**: no need to find the right sex! These are organisms that are both sexes at once, or can change from male to female or female to male.

Life Cycles

- **Life Cycles and diploidy**
- Zygotic meiosis
- Isomorphic
- Alternation of Generations
- Gametic meiosis
- Heteromorphic
- Sporic meiosis

What is a sexual life cycle?

- A sexual life cycle (or a sexual part of a life cycle) is one which includes **meiosis** (which halves ploidy or chromosome number) and **fertilization** (which doubles it)

What is a sexual life cycle?

- A sexual life cycle (or a sexual part of a life cycle) is one which includes **meiosis** (which halves ploidy or chromosome number) and **fertilization** (which doubles it)

- In contrast with asexual reproduction, which involves only mitosis

The three main types of sexual life cycles, differing in the timing of meiosis and fertilization, relative to mitotic growth of multicellular bodies.

**Zygotic meiosis**: zygote divides = 4 haploid cells. Mitosis leads to more haploid cells or a haploid individual. Differentiation produces gametes.

**Gametic meiosis**: 2N individual produces 1N gametes. These fuse to form a 2N zygote. Mitosis = growth.

**Sporic Meiosis**: sporophyte (2N) individual produces 1N spores via meiosis. Spores undergo mitosis = gametophyte (1N individuals). These produce gametes, which fuse to form 2N zygotes = sporophytes.

A “heterokaryotic” stage may happen here in fungi. Note that the nuclei in a heterokaryotic cell are usually haploid nuclei. Thus, the code for the “dikaryotic” condition (one type of heterokaryotic condition) is \( n+n \), rather than \( 2n \). If a cell is not heterokaryotic, it is called mononucleate or monokaryotic.
Figure 13.6 The three main types of sexual life cycles, differing in the timing of meiosis and fertilization, relative to mitotic growth of multicellular bodies.

1. Life cycle of the green alga Ulva

2. Alternation of isomorphic generations

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Figure 6.9 Anatomy of a single plant cell

Note: “protoplast” = everything inside the cell wall.

Figure 6.8 The plasma membrane

Plasma membrane

- Controls passage of materials into and out of cell
- Many compounds cannot pass directly through the membrane, instead they are transported through specific carrier proteins embedded in the membrane

The Endoplasmic Reticulum

Endoplasmic Reticulum

- Smooth ER
  - No ribosomes
  - Involved in lipid synthesis, carbohydrate metabolism, detoxification
- Rough ER
  - Has ribosomes
  - Involved in protein synthesis
  - Primarily proteins destined for export from the cell

The Nucleus and Protein Synthesis

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The Golgi Apparatus
Storage, refinement, and shipping of ER products

Lysosomes
• Sacks of digestive enzymes which break down molecules in the cells
• Digest food, fight invaders, clean house
• pH of 5

Endomembrane system
• ER (smooth and rough), Golgi bodies, vesicles, lysosomes
• Contiguous pathway through cell for the transport of substances
• Vacuoles: membranous sacs with a variety of functions

Vacuoles
• Sacks which can store enzymes, proteins, water, and cellular byproducts
• Plants cells often have large Central Vacuole which holds water and other stuff
• Vacuoles also transport things from one organelle to another within the cell

Ribosomes
• Workbenches for making proteins
• Small non-membranous structures consisting of protein and genetic material (RNA)
• Produced in the nucleus but work outside of it

The Mighty Mitochondria
Sites of cellular respiration and ATP synthesis
Plant Cell

The Chloroplast

- Most of the living world depends on chloroplasts for its energy!
- Two membranes on outside
- Complex membrane structure on inside

Central vacuoles

- Are selective in what passes through tonoplast (membrane enclosing the central vacuole)
- May be used as disposal or storage sites
- Can enlarge by gaining water, resulting in cell growth

Figure 6.27  Microfilaments (actin filaments) are important for cytoplasmic streaming—distribution of materials within a cell

Figure 6.28  Plant cell walls

Protects cell, maintains shape, prevents excess water uptake

Figure 6.28  Plant cell walls

Protects cell, maintains shape, prevents excess water uptake
Figure 6.28 Plant cell walls

Protects cell, maintains shape, prevents excess water uptake

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An introduction to plant tissues

• Tissue: an integrated group of cells with a common function, structure, or both

Three tissue systems of plants

• Dermal tissue - outer protective covering
  – Epidermis/periderm analogous to skin
  – Cuticle - waxy coating to preserve water
• Vascular tissue - transport system
  – Xylem: carries water and nutrients from roots to leaves. Support and food storage too.
  – Phloem: transport organic nutrients (sugar), amino acids, lipids, hormones etc.
• Ground tissue - “everything else”.
  – Pith (internal to vascular), Cortex
  – Function in storage, photosynthesis, & support
Plant Cell Types

- Epidermis
  - Guard Cells
  - Trichomes (appendages). Can be on roots (facilitate absorption), or on ‘hairy’ leaves - reduce solar radiation in xerophytes). Some secrete salts (in halophiles)
  - These cells provide mechanical protection
  - Many are covered with a cuticle (cutin and wax) to minimize water loss

- Ground tissue
  - Parenchyma: photosynthesis and metabolism (storage and secretion).
  - Collenchyma: support (flexible)
  - Sclerenchyma: storage, support (firm), protection

Parenchyma cells

- Alive at maturity
- No secondary walls
- Site of most plant metabolism
- Play a role in wound healing and regeneration

Collenchyma cells

- Living at maturity
- No secondary cell walls or lignin
- Provide flexible support to growing parts of plant
Scelerenchyma cells

- Thick secondary walls, usually with lignin
- Usually dead at maturity
- Usually specialized for support and strengthening of parts that have ceased elongating.
  - Sclereids impart hardness to seed coats, shells of nuts (give pears their grit)
  - Fibers are usually long, slender, tapered (hemp and flax fibers)

Plant Cell Types

- Epidermis
  - Guard Cells
- Ground tissue
  - Parenchyma: photosynthesis and metabolism
  - Collenchyma: support
  - Scelerenchyma: support, storage, protection
- Vascular tissues
  - Xylem: water and nutrients from roots. Also support and food storage
    - Tracheids, vessel elements
  - Phloem: sugars from leaves
    - Sieve-tube members, companion cells

Xylem cells

- Dead at maturity
- Tracheids found in all vascular plants
  - Long and thin with tapered ends
  - Lignin for structural support
  - Less specialized than vessel elements (‘safer’ though)
- Vessel elements found mainly in angiosperms (flowering plants)
  - Generally wider, shorter, and less tapered than tracheids
  - Has perforations for more efficient water flow but perforations are open systems and can be less safe.
Phloem

• Primary and secondary phloem. Primary phloem is often destroyed during elongation of the organ.
• Principal conducting cells are the sieve elements (‘with pores’)

Sieve-tube members

• Alive at maturity, but...
• Lack nucleus, ribosomes, organelles (highly specialized like human red blood cells!)
• Served by nucleus etc. of adjacent companion cells
  – Connected via plasmodesmata