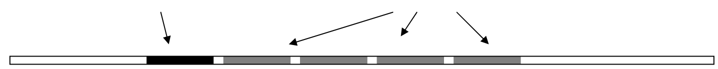
Control of gene expression

- Prokaryotes have operons
- Operon = functionally related genes grouped together on chromosome, switched on or off together.
- control region structural genes



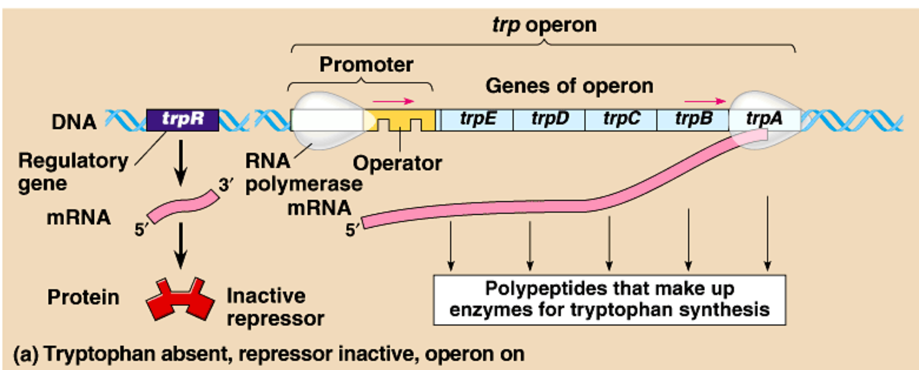
- Eukaryotes don't have operons
- functionally related genes are not necessarily grouped spatially
- coordinated expression is achieved by multiple similar control regions associated with functionally related genes

Example: Trp operon

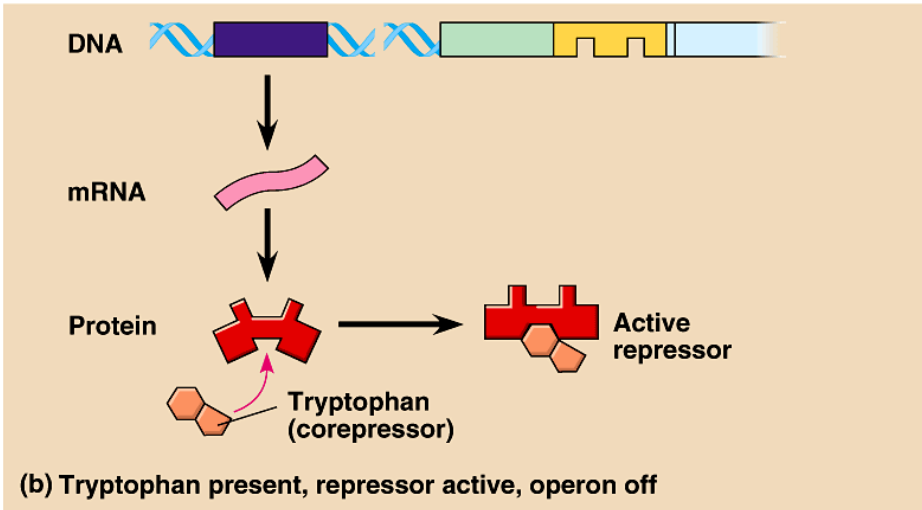
- Genes for enzymes that synthesize the amino acid tryptophan
- Regulatory gene makes repressor protein
- Repressor is activated by binding tryptophan, and blocks transcription by binding operator
- Negative feedback- shuts down operon if there is plenty of tryptophan present

The *trp* operon:

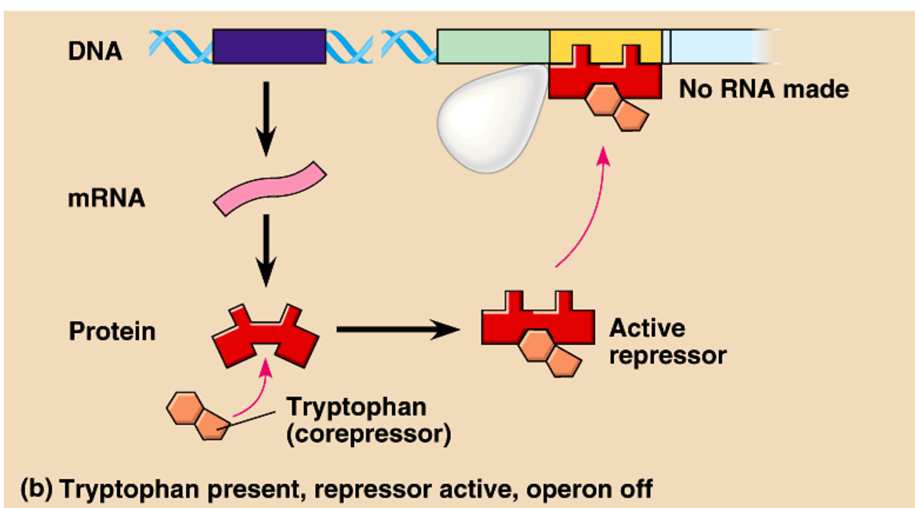
regulated synthesis of repressible enzymes



The *trp* operon: part 1



The *trp* operon: part 2



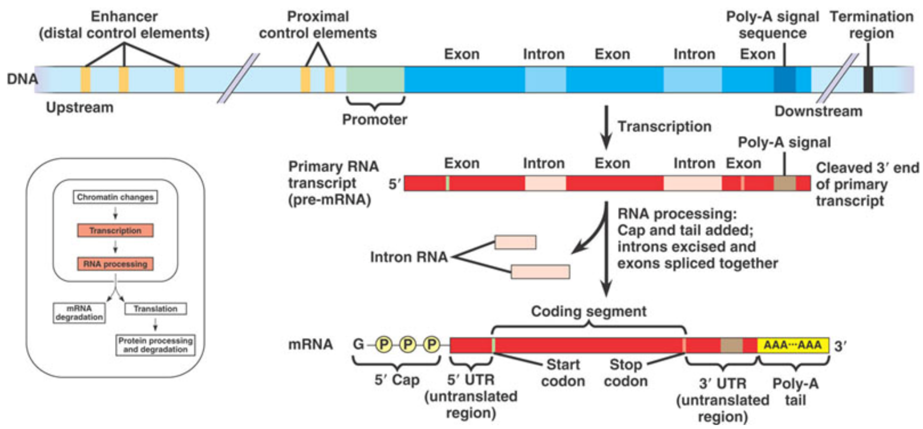
Gene expression in multicellular eukaryotes

- Variety of cell types
- All have same genome
- Which genes get expressed & when
- Roles:
  development,
  cell differentiation,
  metabolic regulation

Control of gene expression

1) Chromatin modifications
   - DNA methylation
   - Histone acetylation
2) Control of transcription
3) Alternative splicing
4) Degradation of mRNA
5) Blockage of translation

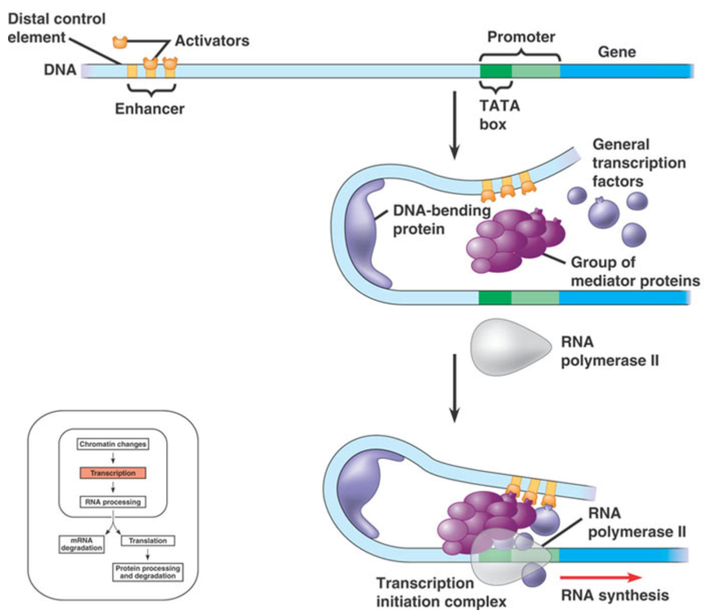
A eukaryotic gene with its
control elements and transcript



2. Control of Transcription (Fig. 13.13-16)

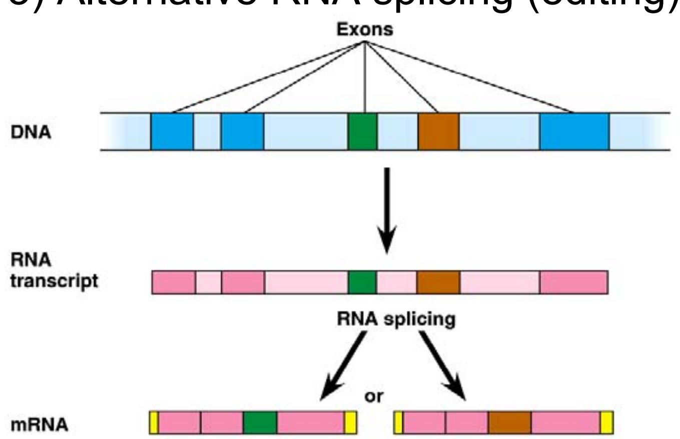
- Control elements (DNA)
  - Enhancer and silencer sequences
- Transcription factors (bind DNA)
  - activators and repressors
- Coordinate control of genes via similar control elements, rather than operons

A model for enhancer action



Control of gene expression, continued

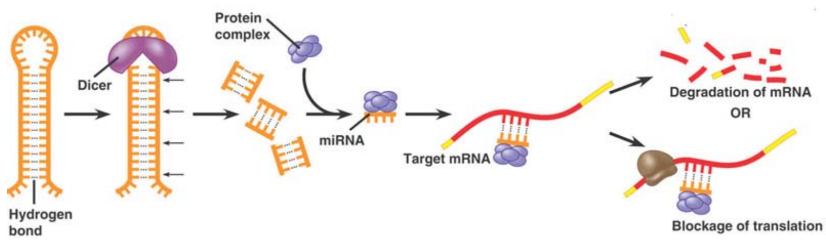
3) Alternative RNA splicing (editing)



Control of gene expression, continued

4. Degradation of mRNA
5. Blockage of translation

siRNA and miRNA



Control of gene expression, continued

Post-translation

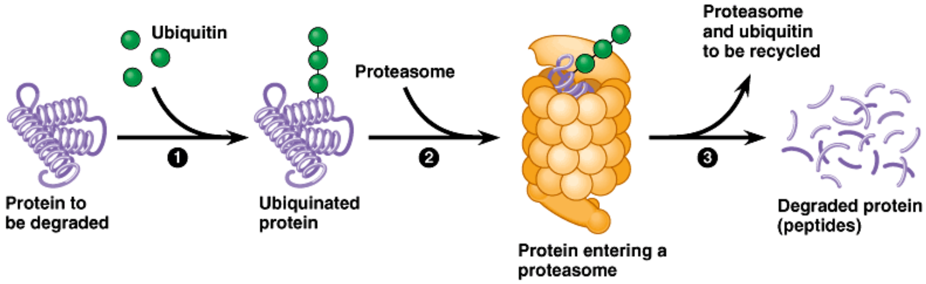
6) Protein processing, transport

7) Control of enzyme activity by effectors and inhibitors

8) Proteasomes degrade ubiquitin-tagged proteins

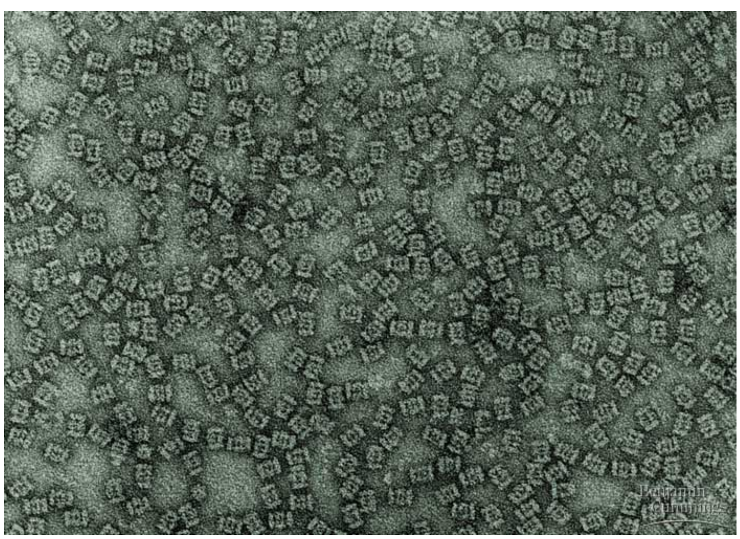
Degradation of a protein by a proteasome

Ubiquitin protein tags other proteins for destruction by proteasomes

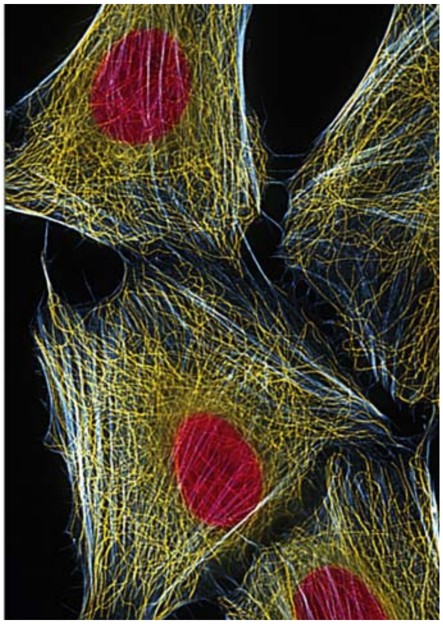


Ubiquitin-proteasome system discovered in ’70s & ’80s
2004 Nobel Prize to Ciechanover, Hershko & Rose.

Proteasomes



Chromosomes, the Cell Cycle, and Cell Division (Chap 15)

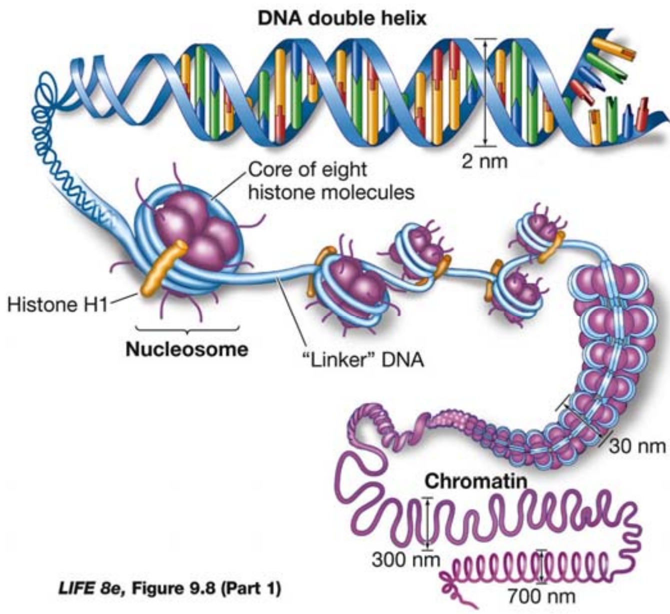


HeLa cells

Henrietta Lacks

- Chromosome structure
  – Prokaryote vs eukaryotes
  – Histones, organization
  – Ploidy
- Cell cycle and reproduction
  – Mitosis
  – Asexual reproduction
  – Meiosis
  – Sexual reproduction

Eukaryote DNA packing



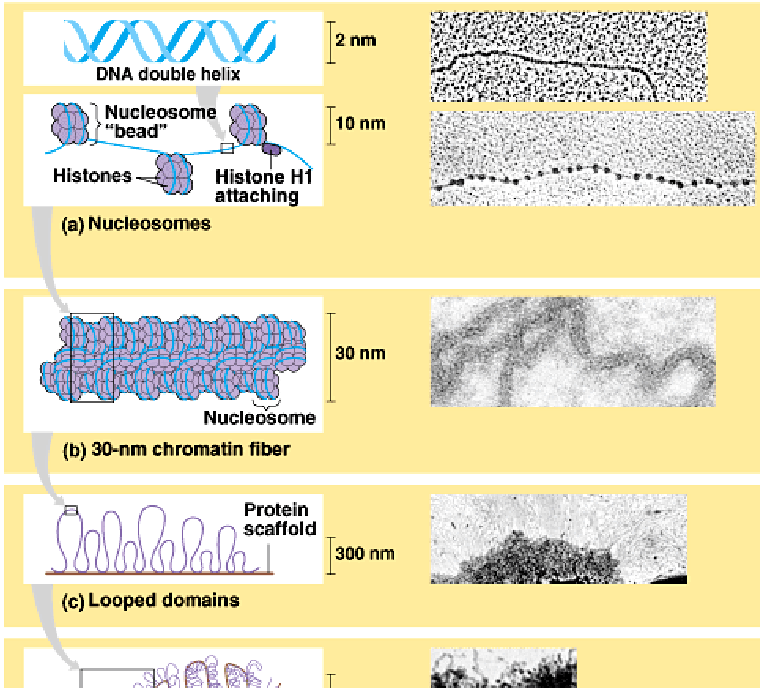
LIFE 8e, Figure 9.8 (Part 1)

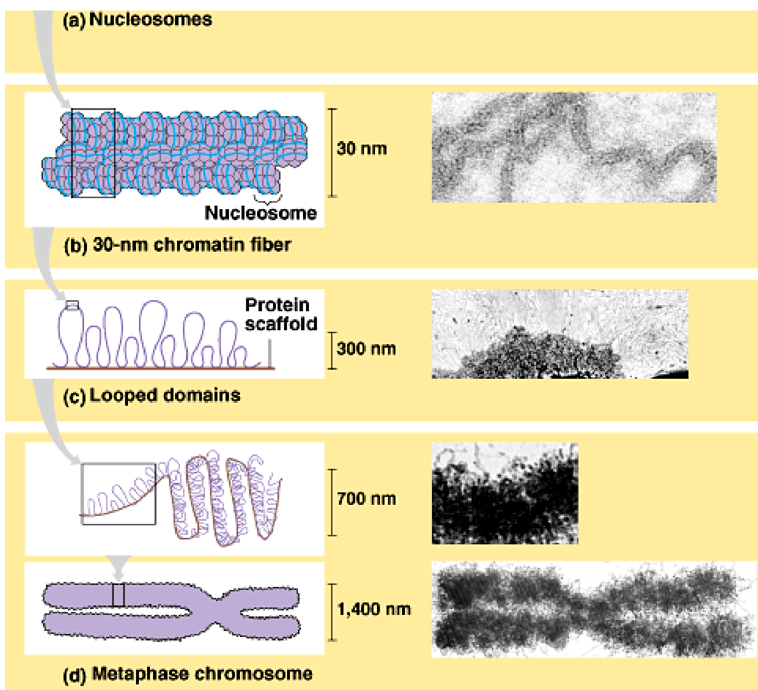
To next figure

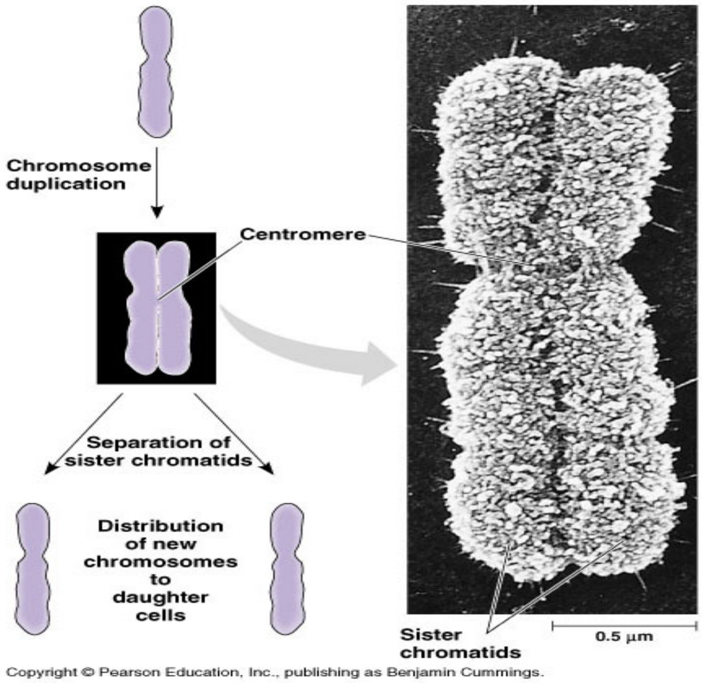
LIFE 8e, Figure 9.8 (Part 2)

Metaphase chromosomes

Organization of "chromatin"







Ploidy

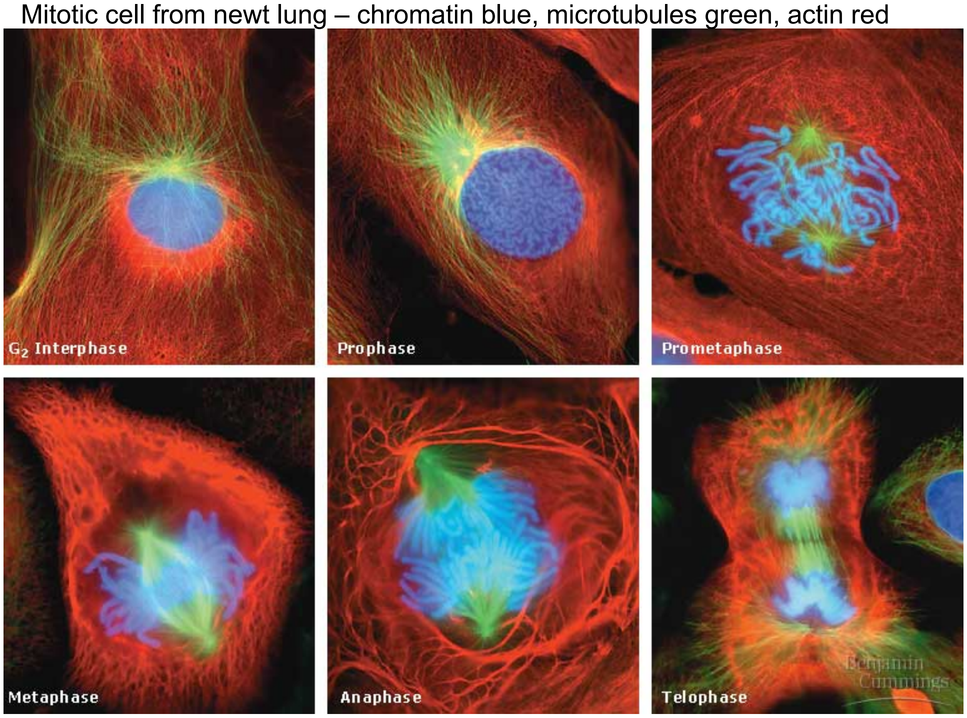
- Haploid
  germ cells

- Diploid
  somatic cells
  homologous pairs of chromosomes

Mitosis

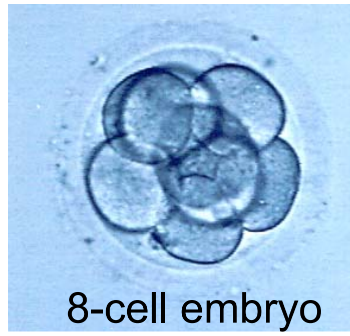
- 1 cell becomes 2 identical daughter cells
- Produces clones.
- asexual reproduction, budding, fragmentation, parthenogenesis
- growth and development, tissue replacement in multicellular organisms
- Learn about mitotic cycle in lab

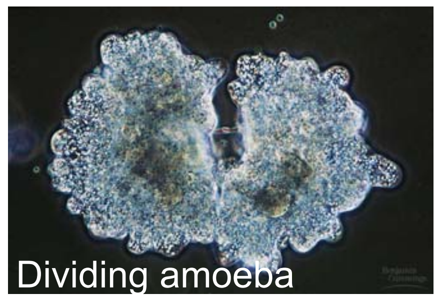
Mitotic cell from newt lung – chromatin blue, microtubules green, actin red



Functions of cell division by mitosis:


Root tip

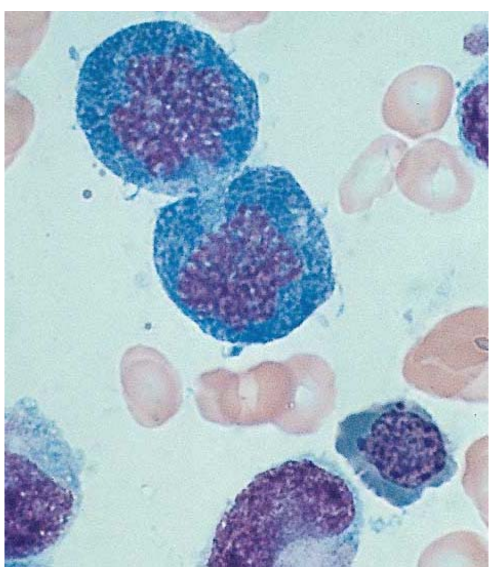

8-cell embryo


Dividing amoeba

Growth,
Development,
Asexual reproduction

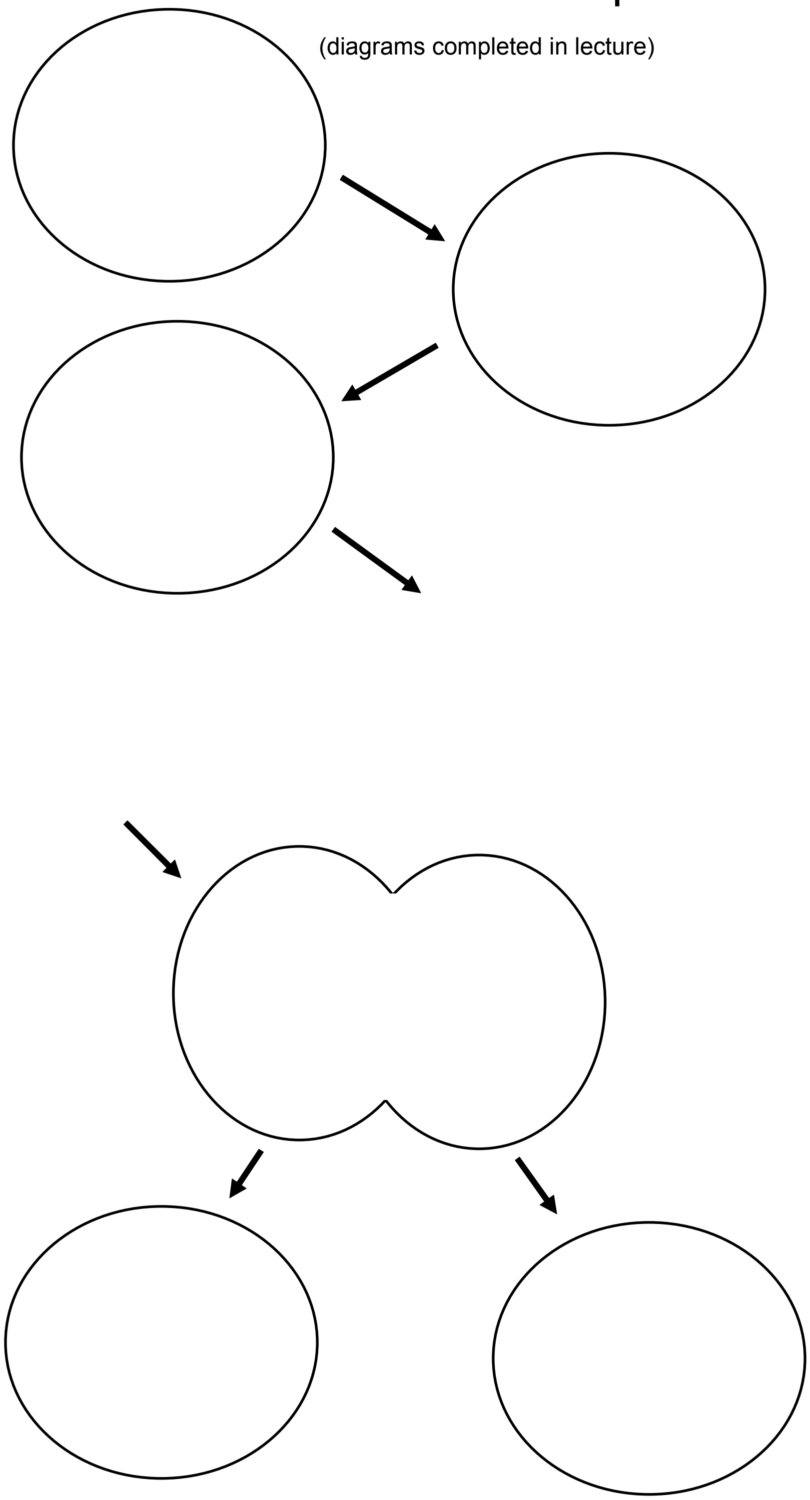
Functions of cell division by mitosis:

Tissue renewal and regeneration



Mitosis of a diploid cell

(diagrams completed in lecture)



Meiosis

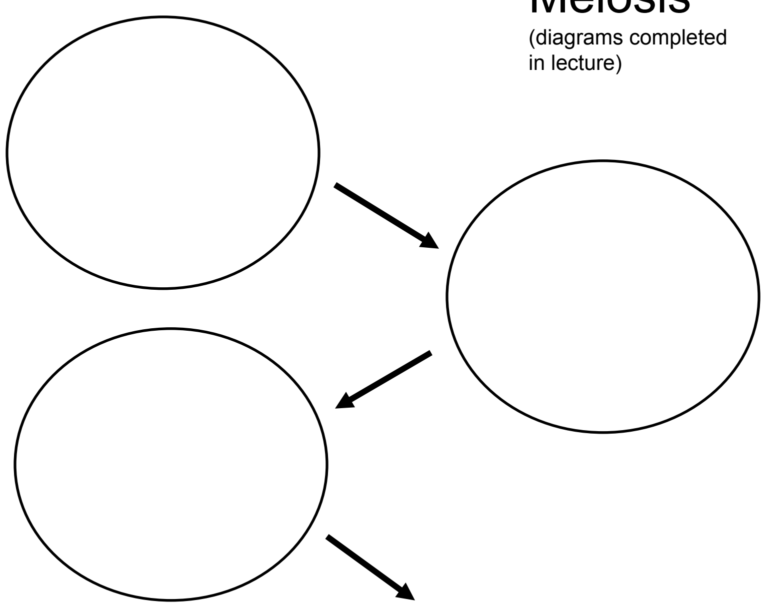
- cell division to make gametes for sexual reproduction
- One diploid cell produces 4 haploid cells (gametes)

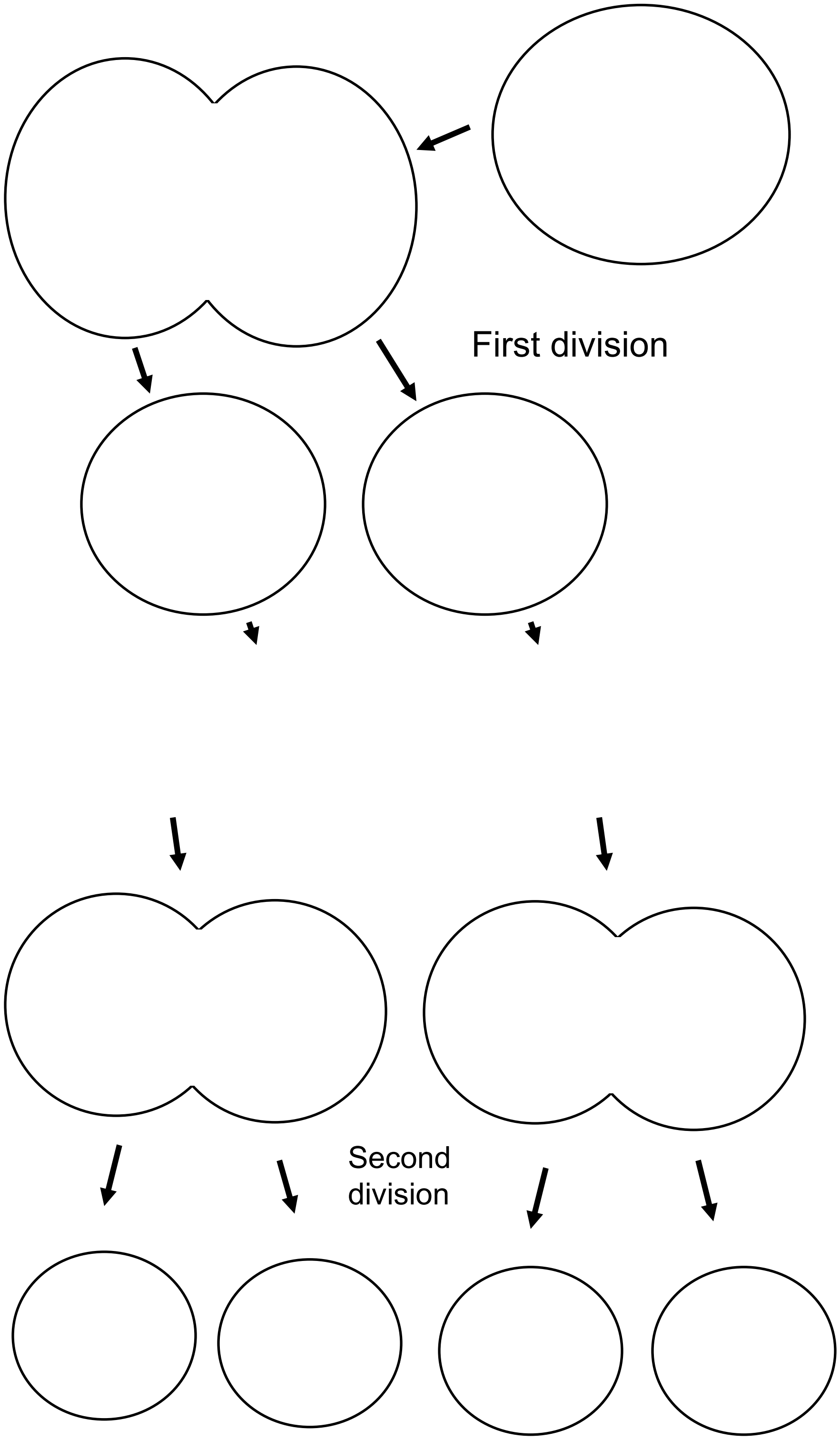
Fertilization

- A pair of haploid gametes (typically egg and sperm) combine to make a diploid zygote

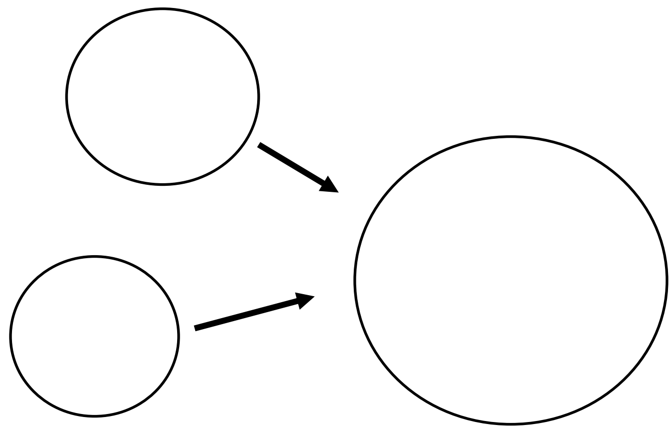
Meiosis

(diagrams completed in lecture)




First division
Second
division

Fertilization



Sexual reproduction

- Meiosis makes haploid gametes
- The gametes are not identical genetically because of: 1) independent assortment of homologues and 2) crossing over
- Fertilization: haploid gametes combine to make diploid zygote with homologous pairs of chromosomes

Why reproduce sexually?

- Genetic recombination produces new combinations of alleles
- Assortment, crossing over, fertilization make new combinations of alleles
  = genetically unique individuals.
- Some combinations may be advantageous- e.g. fast and smart
- Natural selection acts on combinations, not just individual alleles

Inheritance (Chap 16)

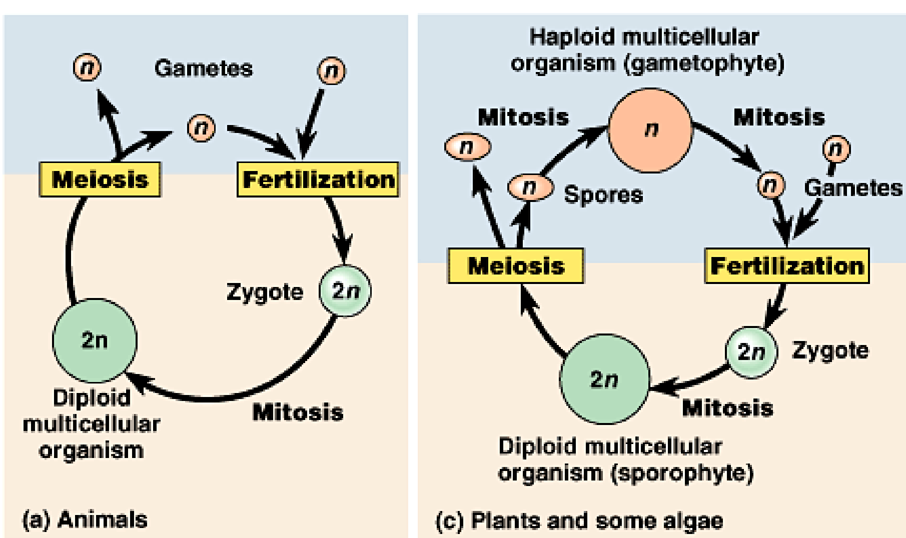
- sexually reproducing organisms inherit homologous pairs of chromosomes:
  one from each parent
- Therefore, offspring inherit a combination of characteristics from parents
- patterns of inheritance first accurately described in 1866 by Gregor Mendel

Gregor Mendel (1822-1884)

Experiments with Plant Hybrids published 1866 in an obscure journal.

His work was at first unnoticed, then rediscovered in 1900 and forms the foundation for understanding inheritance

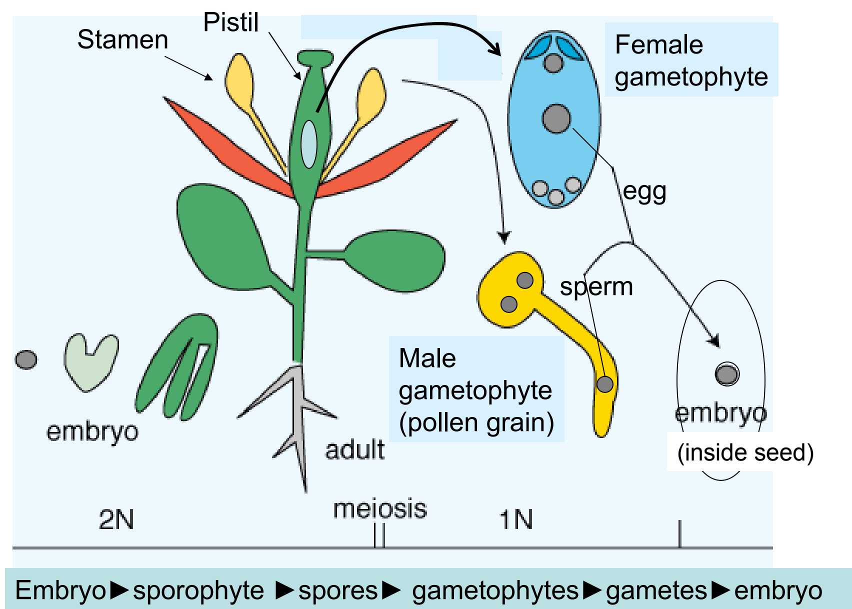
The alternation of haploid and diploid life stages



Flowering plant life cycle

- Diploid sporophyte through meiosis makes haploid gametophytes (female and male).
- The male gametophyte plant is the pollen grain – produces male gamete (sperm) by mitosis
- The female gametophyte plant is within the pistil – produces female gamete (egg) by mitosis
- You can basically “ignore” this complication in considering inheritance

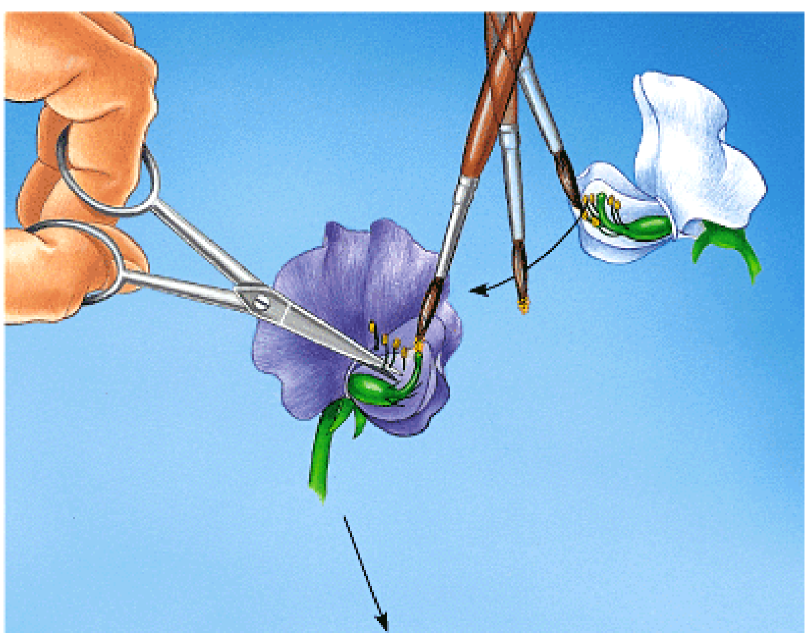
Flowering plant life cycle

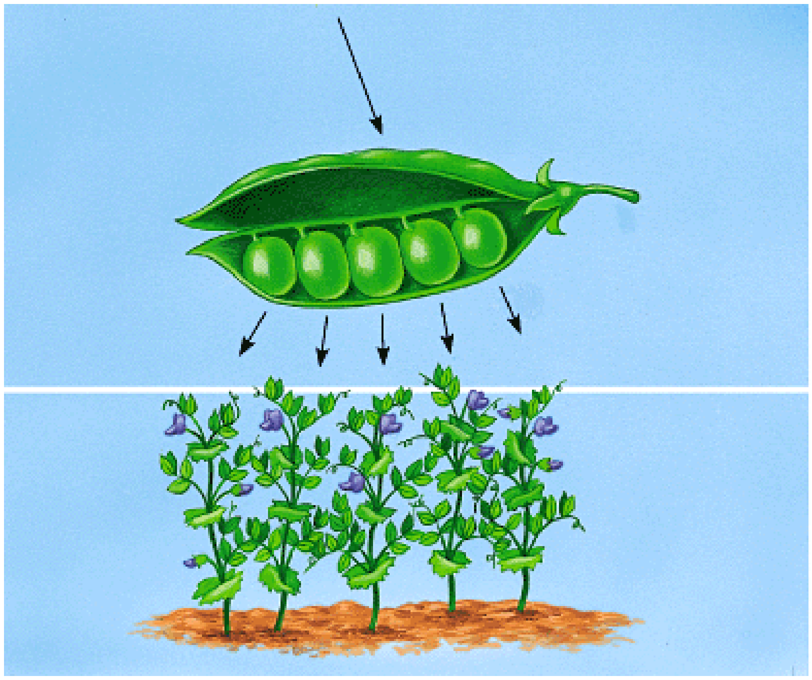


Mendel's experiments

- deduced principles of inheritance without any molecular information
- Grew pea plants and recorded characteristics of parents and offspring over many generations
- Systematic crosses between parent plants of known lineage
- Selfing versus outcrossing

See Figure 16.3-4 in Brooker

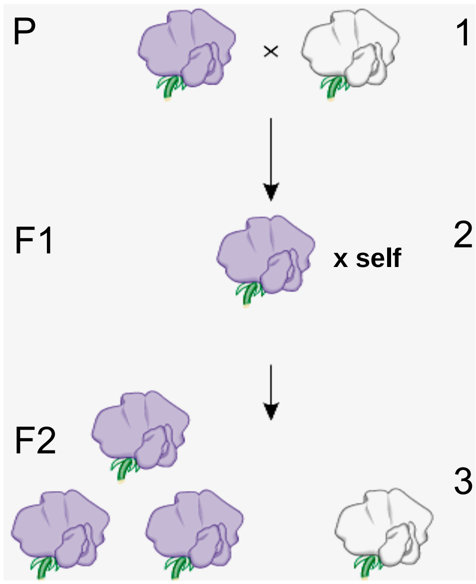




Example- inheritance of flower color

- Two colors- purple, white.
- Some individuals always produced self similar offspring if self-fertilized: homozygous ("similar offspring")
- Others produced offspring of both colors when selfed: heterozygous ("different offspring")

Monohybrid test cross (see Fig 10.3 p. 211 Sadava)

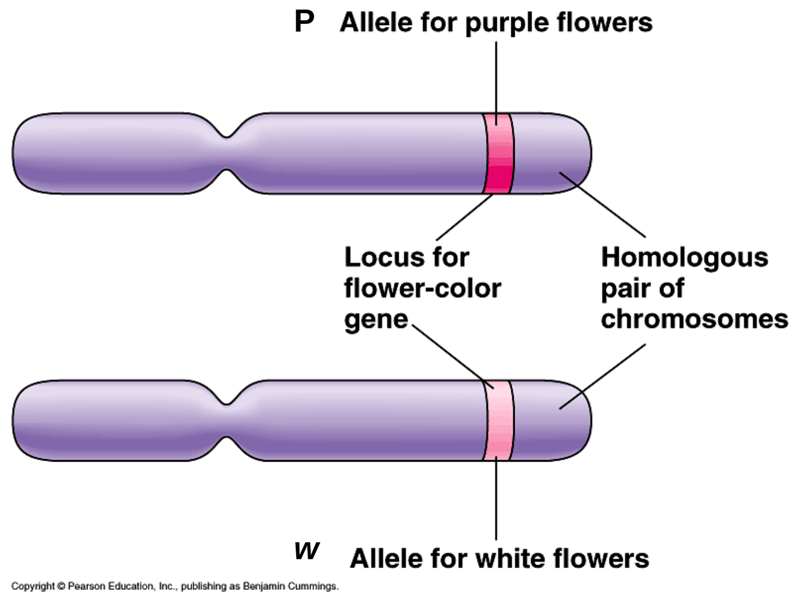


1. Crossed two homozygous parents…
2. F1 all purple. Crossed F1….
3. Observed 3:1 phenotype ratio in F2

Explanation

- There is a gene that affects flower color
- The gene exists in two alternative forms (alleles). Call them P and *w*
- Allele P codes for purple protein
- Allele *w* codes for a colorless version of the protein

Alleles are alternative versions of a gene



Explanation, continued

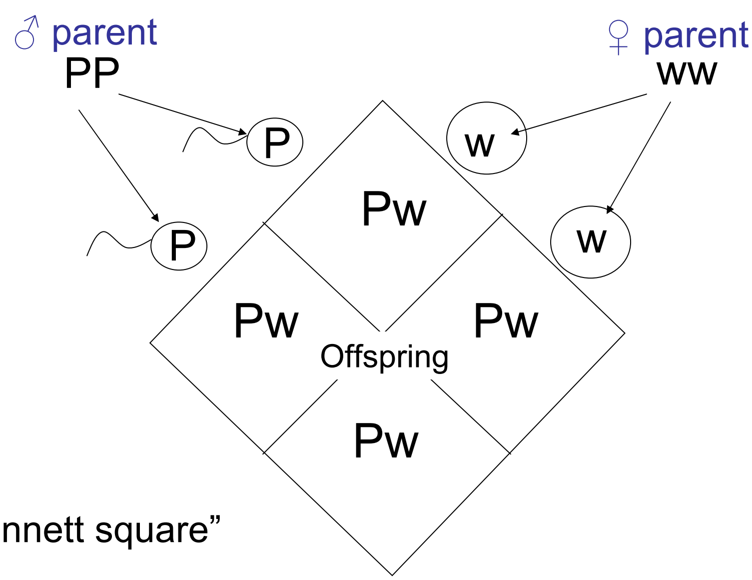
- Diploid individual inherits two copies of each gene.
- Therefore, there are three possible genotypes:

  PP (homozygous P)
  Pw (heterozygous)
  ww (homozygous w)

What about gamete genotypes?

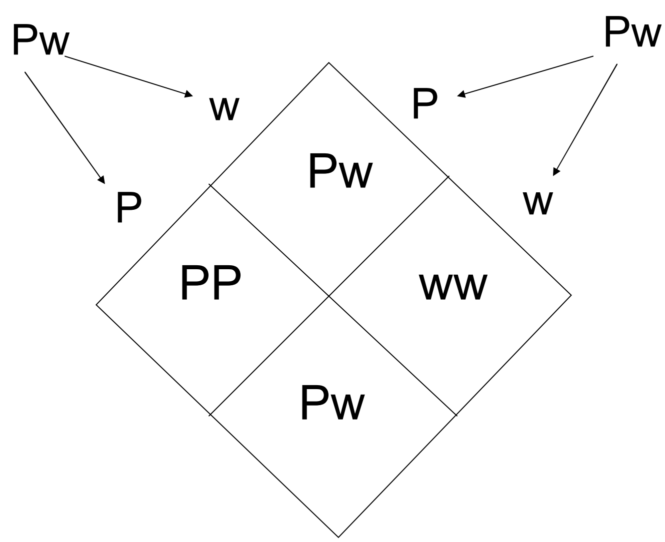
- PP → meiosis → P P P P (all P)
- Pw → meiosis → P P w w (50/50)
- ww → meiosis → w w w w (all w)

F1 generation: all heterozygous

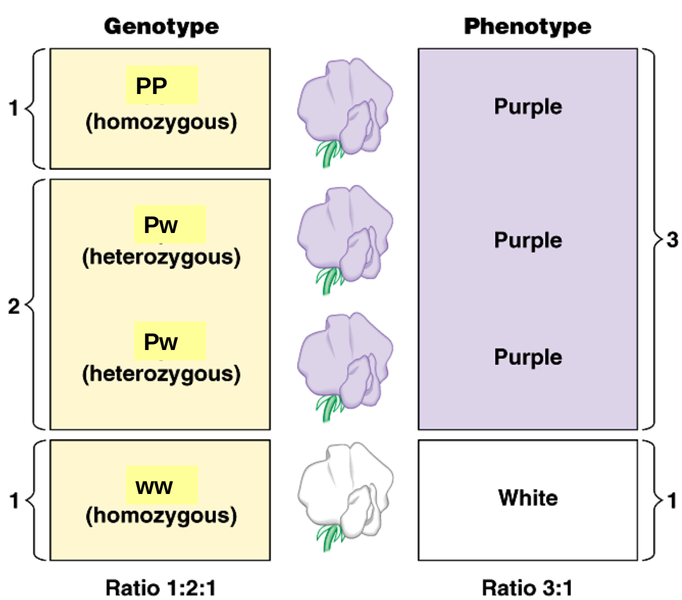


"Punnett square"

F2 generation:



Genotype versus phenotype



Dominant & Recessive

- The dominant character is expressed if a dominant allele is present.
- A recessive character is expressed only if a dominant allele is not present
- Both PP and Pw express the dominant phenotype (purple flowers)
- Only ww individuals express the recessive phenotype (white flowers)

Monohybrid crosses

- Mendel tested inheritance of seven different characters, corresponding to seven different gene loci
- For each character, he tested two different forms, corresponding to different alleles.
- In each case, one allele was dominant and the other recessive

TABLE 10.1

Mendel's Results from Monohybrid Crosses

Parental generation phenotypes: Dominant		Parental generation phenotypes: Recessive	F_2 generation phenotypes: Dominant	F_2 generation phenotypes: Recessive	Total	Ratio
Spherical seeds	×	Wrinkled seeds	5,474	1,850	7,324	2.96:1
Yellow seeds	×	Green seeds	6,022	2,001	8,023	3.01:1
Purple flowers	×	White flowers	705	224	929	3.15:1
Inflated pods	×	Constricted pods	882	299	1,181	2.95:1
Green pods	×	Yellow pods	428	152	580	2.82:1
Axial flowers	×	Terminal flowers	651	207	858	3.14:1
Tall stems (1 m)	×	Dwarf stems (0.3 m)	787	277	1,064	2.84:1

***LIFE 8e*, Table 10.1**

Krogh's rule

- Definition

- Why pea plants?
- Selfing vs crossing
- Large numbers of offspring
- Statistical nature of inheritance

Vocabulary review

- Genotype
- Phenotype
- Allele
- Gene locus (plural = loci)
- Blending & particulate inheritance
- Homozygous & heterozygous
- Dominant & recessive

Dihybrid test cross

- Mendel analyzed inheritance of pairs of characters
- Started with parents homozygous for two characters
- For example, seed color and seed shape
- Y = yellow *y* = green
- R = round *r* = wrinkled

Nine possible genotypes

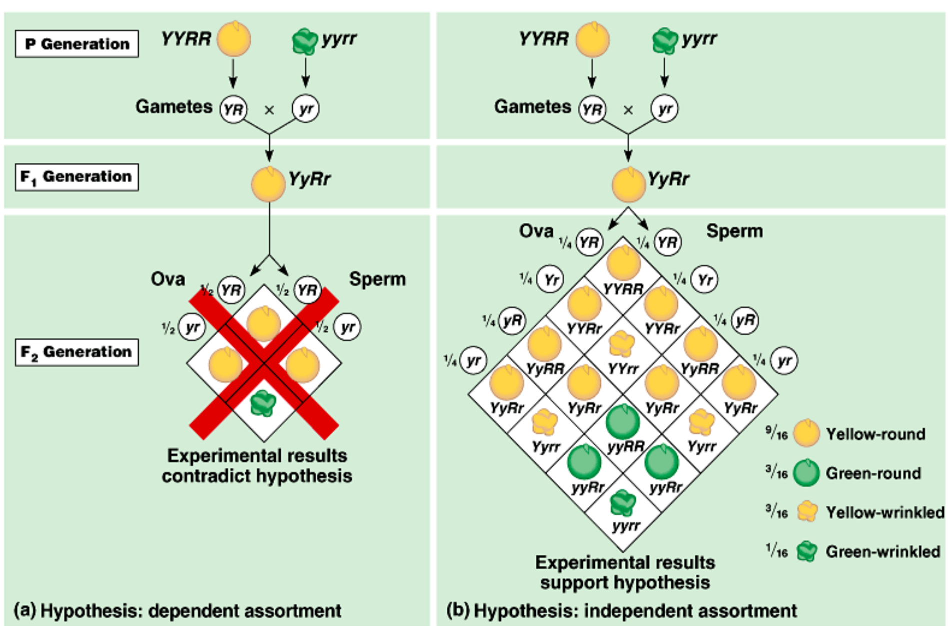
YYRR YYRr YYrr

YyRR YyRr Yyrr

yyRR yyRr yyrr

Four possible phenotypes

Yellow, round	YYRR YYRr YyRR YyRr
Yellow, wrinkled	YYrr Yyrr
Green, round	yyRR yyRr
Green, wrinkled	yyrr



F2 phenotype predictions

- 9/16 smooth, yellow
- 3/16 smooth, green
- 3/16 wrinkled, yellow
- 1/16 wrinkled, green

- 9:3:3:1 was Mendel's result for all dihybrid combinations of his seven gene loci.

Mendel's "laws"

- Segregation: for each character, an individual inherits two alleles (one from each parent): these separate again during gamete formation.
- Independent assortment: the alleles of different genes assort independently of one another (the combinations of alleles are not preserved in the next generation)

Rules of Probability

- Multiplication: the probability of two events occurring together is the product of their individual probabilities.
- Addition: the probability of an outcome that can occur in several ways is the sum of the probabilities of those events.

Examples- coin tossing

- What is the chance of tossing heads?
- What is the probability of tossing heads three times in a row?
- If you throw heads 3 times in a row, what is the probability of then throwing tails?

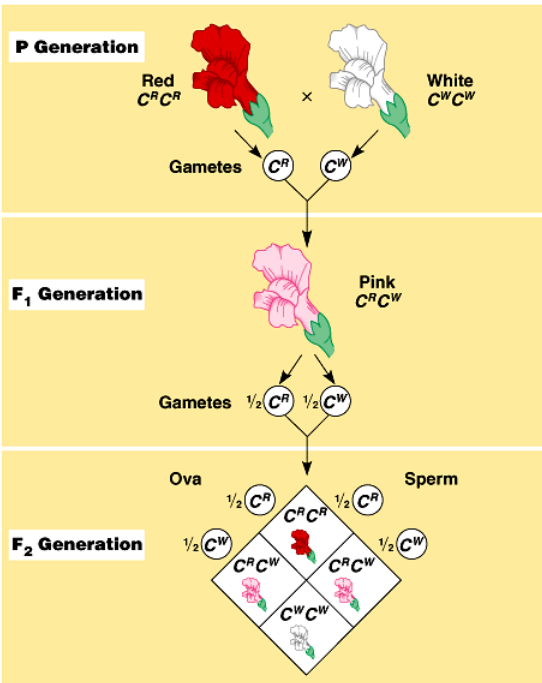
Dominance

- Describes effect of allele on phenotype, when paired with a different allele
- Complete dominance- phenotype of heterozygotes is the same as that of homozygous dominant individuals.
- Incomplete dominance- heterozygotes have intermediate phenotype
- Codominance- heterozygote expresses both alleles

Incomplete dominance

- Allele C^R makes red pigment
- Allele C^W doesn't

- C^RC^R - red
- C^RC^W – pink
- C^WC^W- white



Codominance: ABO blood types

- phenotype is the presence of proteins on surface of red blood cells
- Three alleles: I^A , I^B and i

Phenotypes	Genotypes
Type A has protein A	I^AI^A or I^Ai
Type B has protein B	I^BI^B or I^Bi
Type AB has both A, B	I^AI^B
Type O has neither	ii

- I^A and I^B are codominant, i is recessive

More complications

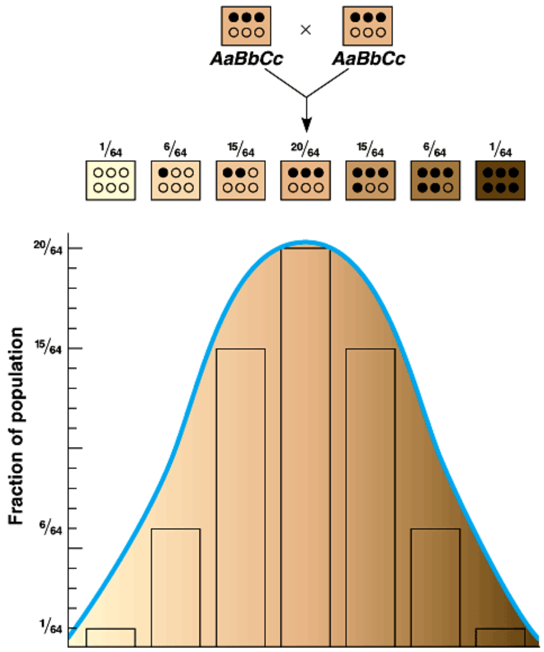
- Polygenic traits- determined by effects of two or more genes
- Pleiotropy- gene has multiple effects on phenotype
- Epistasis - one gene affects the expression of another
- Phenotypic plasticity – environment influences phenotype

Polygenic traits

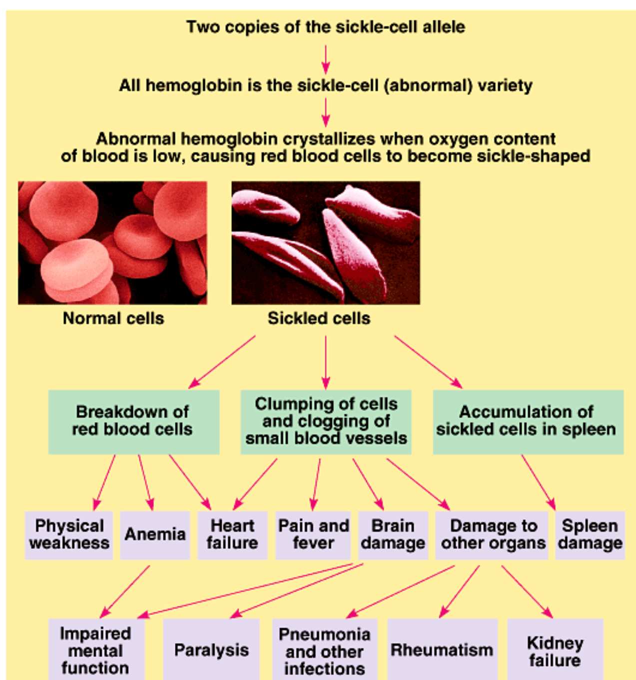
Continuous versus discontinuous traits

Quantitative genetics =study of traits that are continuous, e.g.

- Crop Yield
- Disease Resistance
- Weight Gain in Animals
- Fat Content of Meat
- IQ
- Blood Pressure



Pleiotropic effects of sickle-cell hemoglobin gene

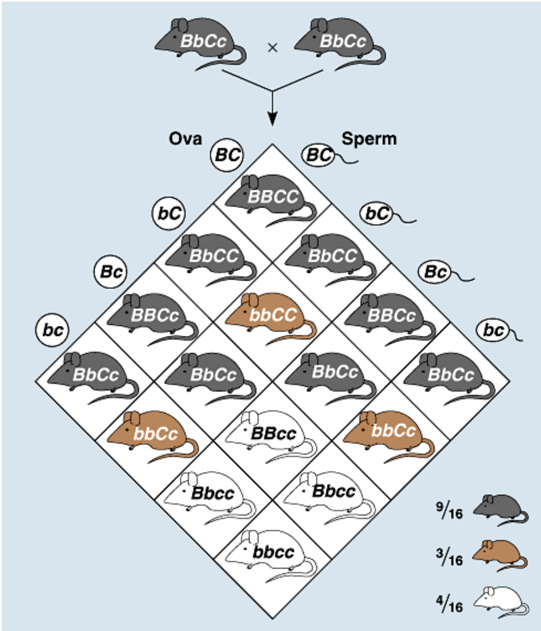


<u>Epistatic</u> effect of locus C on locus B

Allele C permits synthesis of dihydroxyindole

cc can't make dihydroxyindole

Locus B enzyme converts brown dihydroxyindole to black eumelanin



Phenotypic plasticity

soil pH affects *Hydrangea* flower color