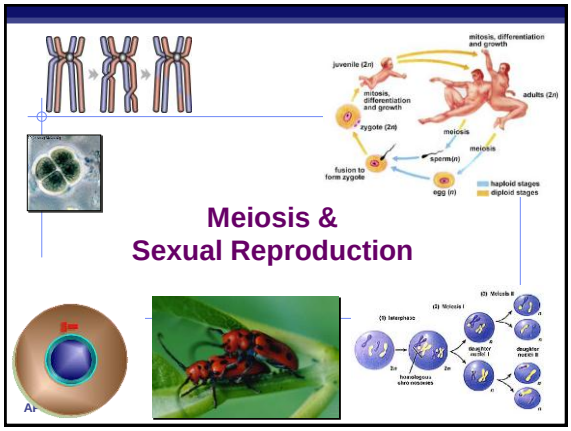
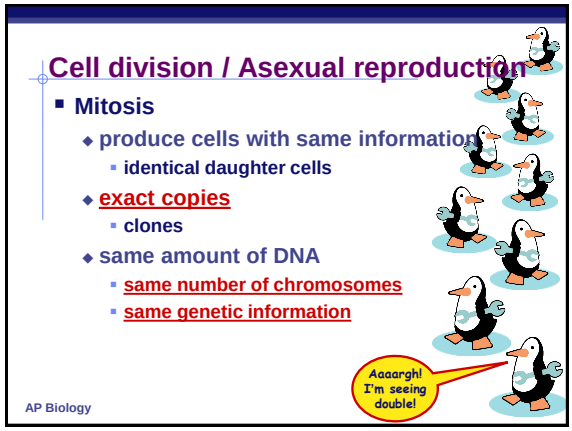
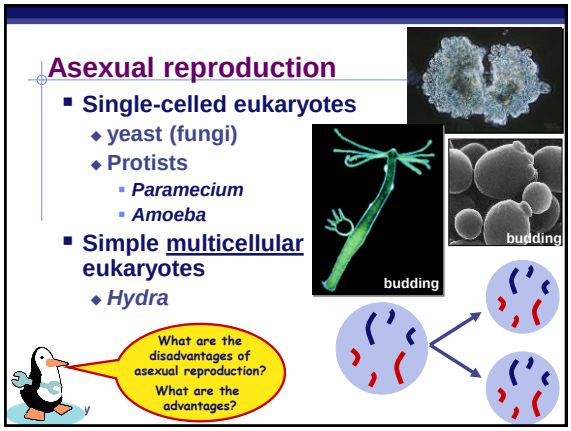
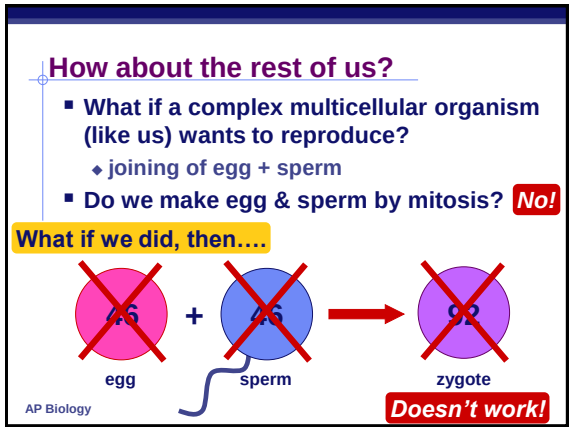
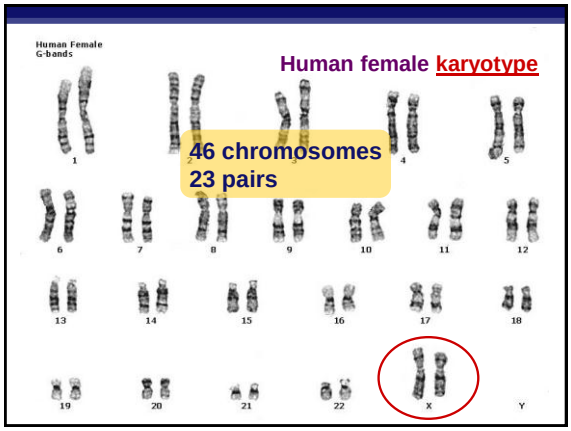
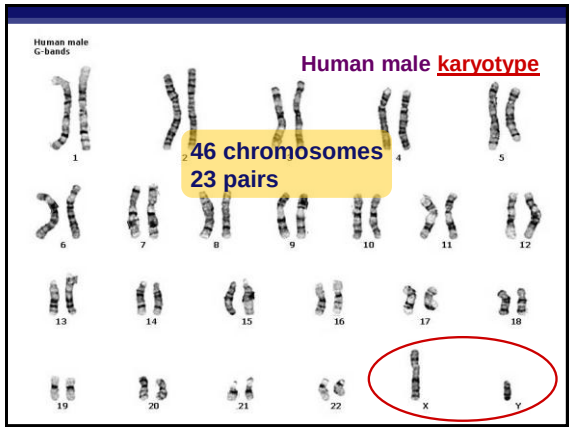

mitosis, differentiation and growth
juvenile (2n)
adults (2n)
zygote (2n)
meiosis
meiosis
sperm(n)
fusion to form zygote
egg (n)
haploid stages
diploid stages
Meiosis &
Sexual Reproduction


Cell division / Asexual reproduction
Mitosis
produce cells with same information
identical daughter cells
exact copies
clones
same amount of DNA
same number of chromosomes
same genetic information
Aaaargh! I'm seeing double!
AP Biology


Asexual reproduction
Single-celled eukaryotes
yeast (fungi)
Protists
Paramecium
Amoeba
Simple multicellular eukaryotes
Hydra
budding
budding
What are the disadvantages of asexual reproduction? What are the advantages?

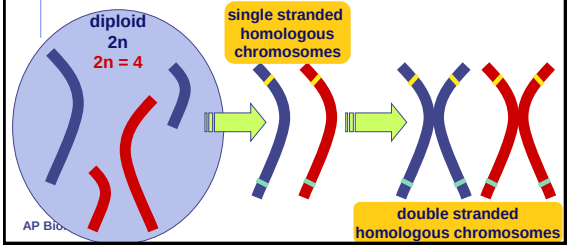

How about the rest of us?
What if a complex multicellular organism (like us) wants to reproduce?
joining of egg + sperm
Do we make egg & sperm by mitosis? No!
What if we did, then….
46
+
46
92
egg
sperm
zygote
AP Biology
Doesn't work!


Human Female G-bands
Human female karyotype
46 chromosomes
23 pairs


Human male G-bands
Human male karyotype
46 chromosomes
23 pairs

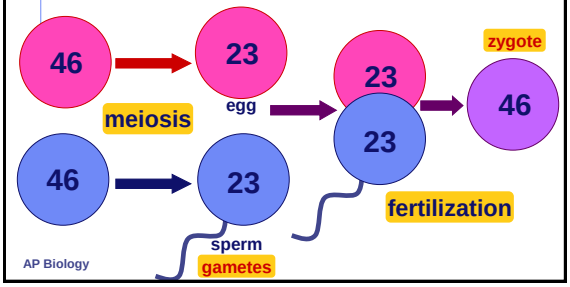
Homologous chromosomes

- Paired chromosomes
  - both chromosomes of a pair carry "matching" genes
    - control same inherited characters
    - homologous = same information



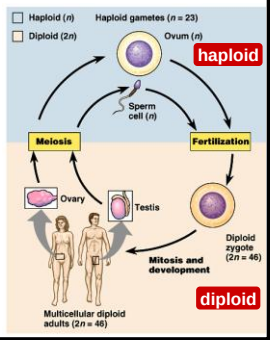
How do we make sperm & eggs?

- Must reduce 46 chromosomes → 23
  - must reduce the number of chromosomes by half

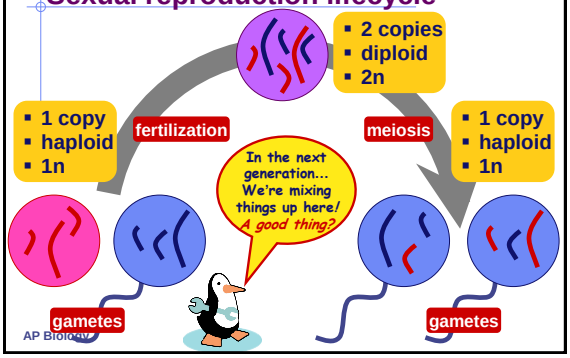


Meiosis: production of gametes

- Alternating stages
  - chromosome number must be reduced
    - diploid → haploid
    - 2n → n
      - humans: 46 → 23
    - meiosis reduces chromosome number
    - makes gametes
  - fertilization restores chromosome number
    - haploid → diploid
    - n → 2n

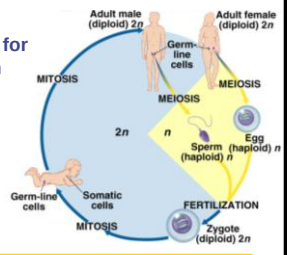


Sexual reproduction lifecycle



Meiosis

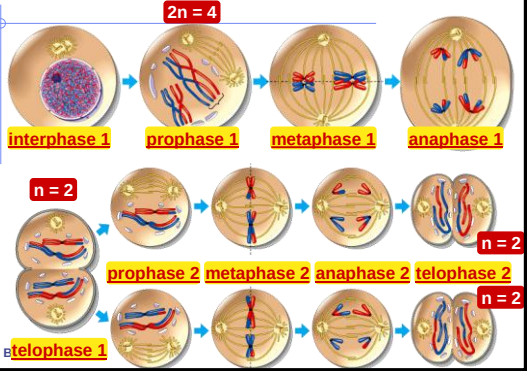
- Reduction Division
  - special cell division for sexual reproduction
  - reduce 2n → 1n
  - diploid → haploid
    - "two" → "half"
  - makes gametes
    - sperm, eggs



Warning: meiosis evolved from mitosis, so stages & "machinery" are similar but the processes are radically different. Do not confuse the two!

Overview of meiosis

I.P.M.A.T.P.M.A.T



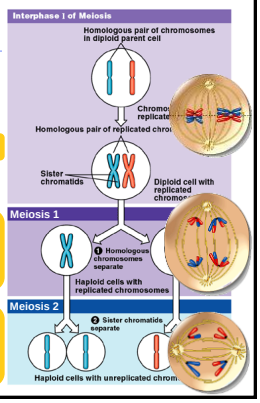
Double division of meiosis

DNA replication

I can't hear you!

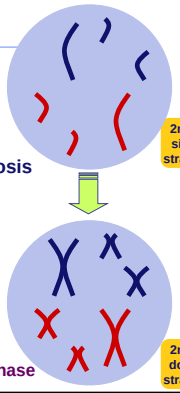
1st division of meiosis separates homologous pairs

2nd division of meiosis separates sister chromatids



Preparing for meiosis

- 1st step of meiosis
  - Duplication of DNA
  - Why bother?
    - meiosis evolved after mitosis
    - convenient to use "machinery" of mitosis
    - DNA replicated in S phase of interphase of MEIOSIS (just like in mitosis)



AP Biology

M1 prophase

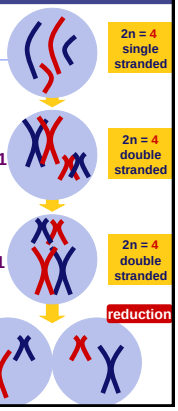
Meiosis 1

- 1st division of meiosis separates homologous pairs

synapsis

tetrad

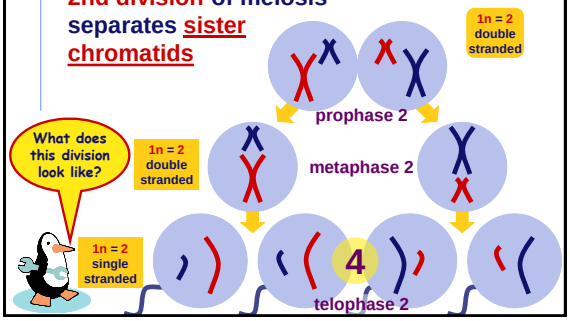
I can't hear you!



Meiosis 2

- 2nd division of meiosis separates sister chromatids

What does this division look like?



Steps of meiosis

- Meiosis 1
  - interphase
  - prophase 1
  - metaphase 1
  - anaphase 1
  - telophase 1
- Meiosis 2
  - prophase 2
  - metaphase 2
  - anaphase 2
  - telophase 2

1st division of meiosis separates homologous pairs

(2n → 1n)

"reduction division"

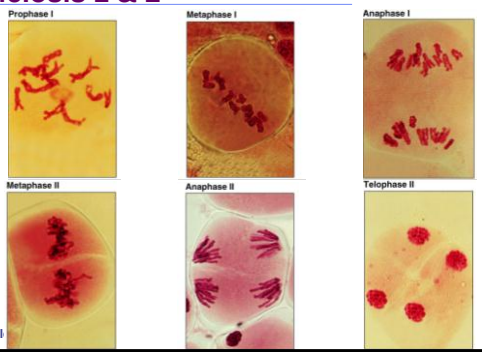
2nd division of meiosis separates sister chromatids

(1n → 1n)

* just like mitosis *

AP Biology

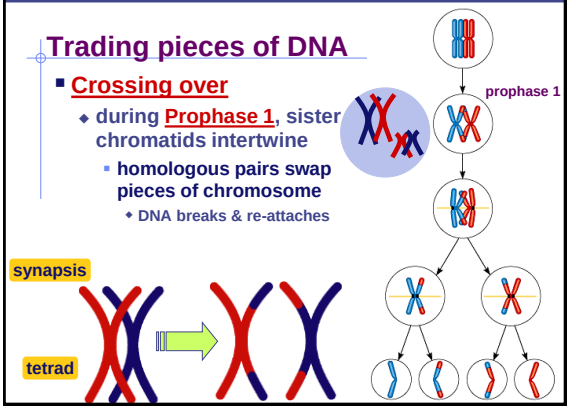
Meiosis 1 & 2



AP Biol

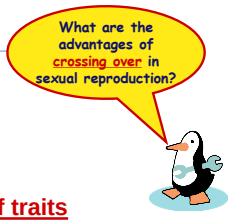
Trading pieces of DNA

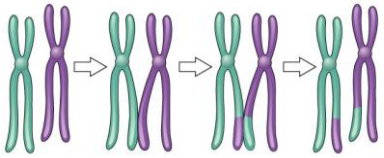
- Crossing over
  - during Prophase 1, sister chromatids intertwine
    - homologous pairs swap pieces of chromosome
      - DNA breaks & re-attaches



Crossing over

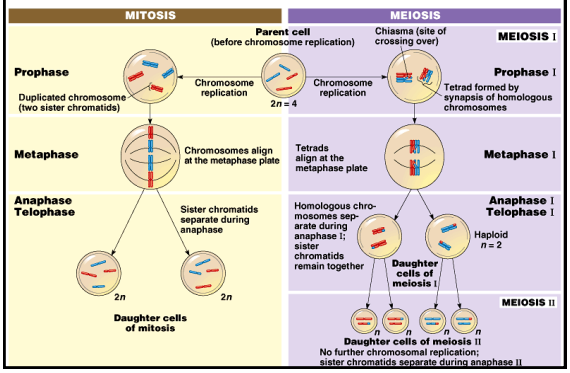
- 3 steps
  - cross over
  - breakage of DNA
  - re-fusing of DNA
- New combinations of traits





AP Biology

Mitosis vs. Meiosis



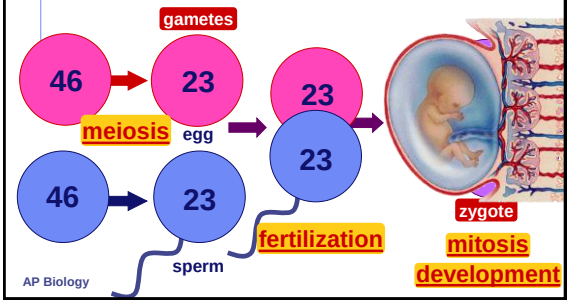
Mitosis vs. Meiosis

Mitosis	Meiosis
1 division	2 divisions
daughter cells genetically identical to parent cell	daughter cells genetically different from parent
produces 2 cells	produces 4 cells
2n → 2n	2n → 1n
produces cells for growth & repair	produces gametes
no crossing over	crossing over

AP Biology

Putting it all together…

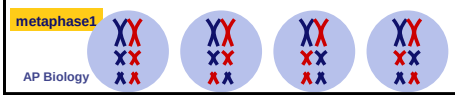
meiosis → fertilization → mitosis + development



AP Biology

The value of sexual reproduction

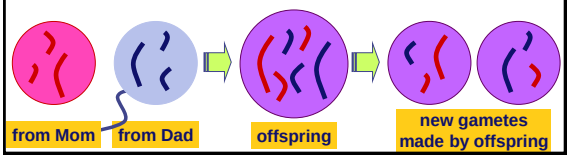
- Sexual reproduction introduces genetic variation
  - genetic recombination
    - independent assortment of chromosomes
      - random alignment of homologous chromosomes in Metaphase 1
  - crossing over
    - mixing of alleles across homologous chromosomes
  - random fertilization
    - which sperm fertilizes which egg?
- Driving evolution
  - providing variation for natural selection



AP Biology

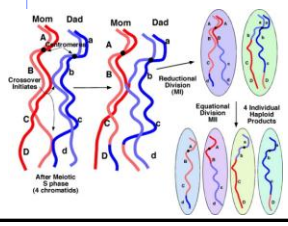
Variation from genetic recombination

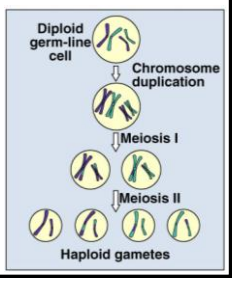
- Independent assortment of chromosomes
  - meiosis introduces genetic variation
  - gametes of offspring do not have same combination of genes as gametes from parents
    - random assortment in humans produces 2^{23} (8,388,608) different combinations in gametes



Variation from crossing over

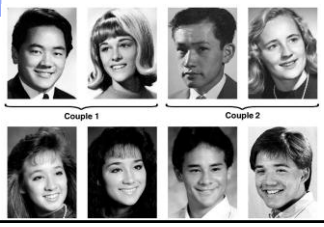
- Crossing over creates completely new combinations of traits on each chromosome
  - creates an infinite variety in gametes

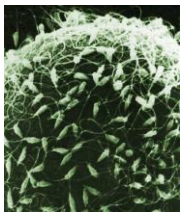




Variation from random fertilization

- Sperm + Egg = ?
  - any 2 parents will produce a zygote with over 70 trillion (2^{23} x 2^{23}) possible diploid combinations





AP

Sexual reproduction creates variability

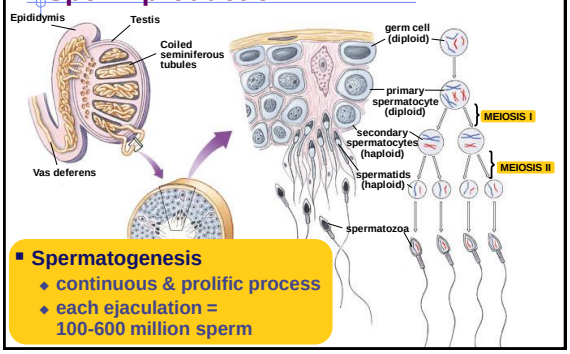
Sexual reproduction allows us to maintain both genetic similarity & differences.

Baldwin brothers

Jonas Brothers

Martin & Charlie Sheen, Emilio Estevez

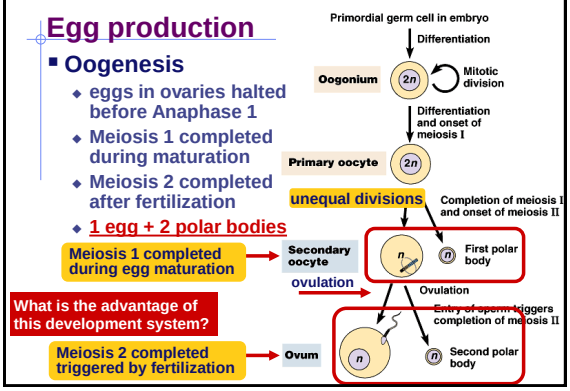
Sperm production



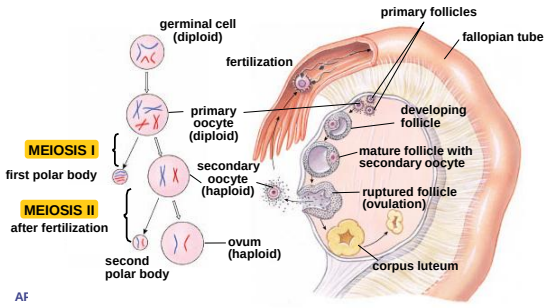
- Spermatogenesis
  - continuous & prolific process
  - each ejaculation = 100-600 million sperm

Egg production

- Oogenesis
  - eggs in ovaries halted before Anaphase 1
  - Meiosis 1 completed during maturation
  - Meiosis 2 completed after fertilization
  - 1 egg + 2 polar bodies



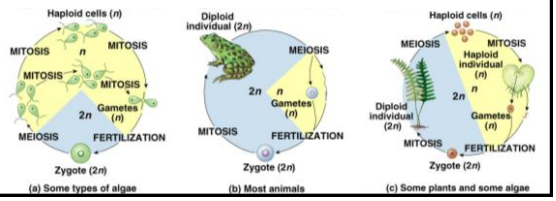
Oogenesis

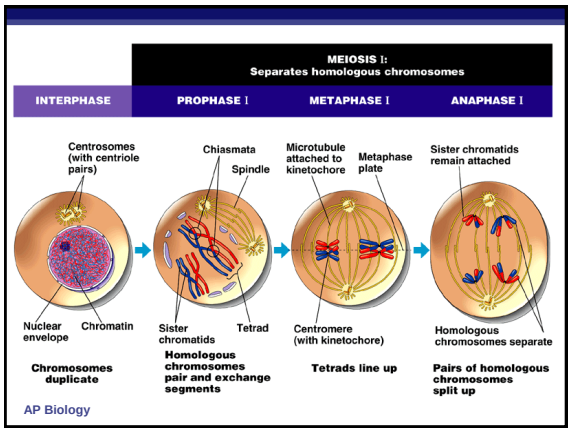


AP

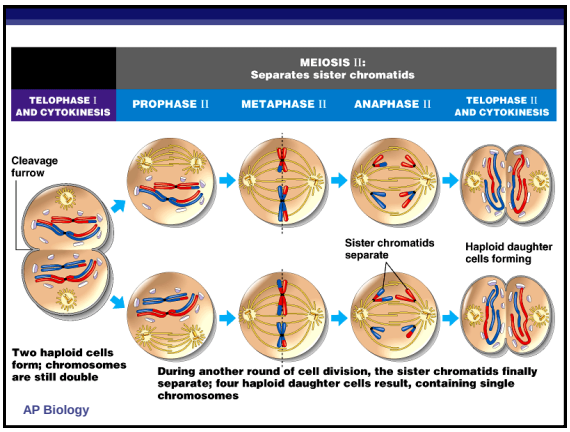
Differences across kingdoms

- Not all organisms use haploid & diploid stages in same way
  - which one is dominant (2n or n) differs
  - but still alternate between haploid & diploid
    - must for sexual reproduction

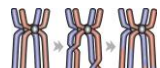




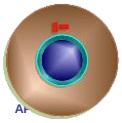
AP Biology

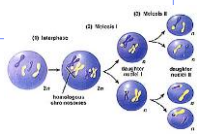


AP Biology



Errors of Meiosis
Chromosomal Abnormalities

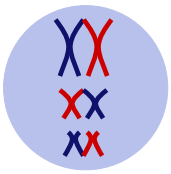




AP

Chromosomal abnormalities

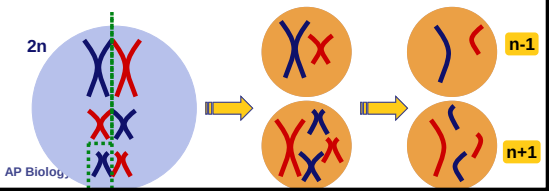
- Incorrect number of chromosomes
  - nondisjunction
    - chromosomes don't separate properly during meiosis
  - breakage of chromosomes
    - deletion
    - duplication
    - inversion
    - translocation



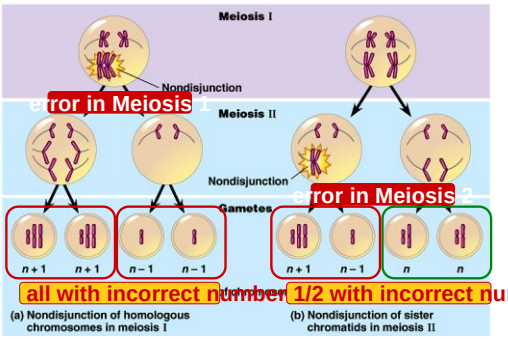
AP Biology

Nondisjunction

- Problems with meiotic spindle cause errors in daughter cells
  - homologous chromosomes do not separate properly during Meiosis 1
  - sister chromatids fail to separate during Meiosis 2
  - too many or too few chromosomes

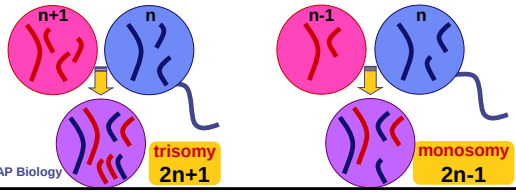


Alteration of chromosome number



Nondisjunction

- Baby has wrong chromosome number
  - trisomy
    - cells have 3 copies of a chromosome
  - monosomy
    - cells have only 1 copy of a chromosome

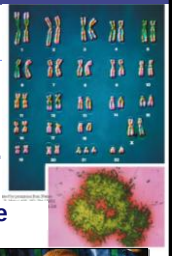


Human chromosome disorders

- High frequency in humans
  - most embryos are spontaneously aborted
  - alterations are too disastrous
  - developmental problems result from biochemical imbalance
    - imbalance in regulatory molecules?
      - hormones?
      - transcription factors?
- Certain conditions are tolerated
  - upset the balance less = survivable
  - but characteristic set of symptoms = syndrome

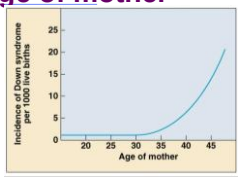
Down syndrome

- Trisomy 21
  - 3 copies of chromosome 21
  - 1 in 700 children born in U.S.
- Chromosome 21 is the smallest human chromosome
  - but still severe effects
- Frequency of Down syndrome correlates with the age of the mother



Down syndrome & age of mother

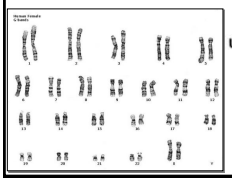
Mother's age	Incidence of Down Syndrome
Under 30	<1 in 1000
30	1 in 900
35	1 in 400
36	1 in 300
37	1 in 230
38	1 in 180
39	1 in 135
40	1 in 105
42	1 in 60
44	1 in 35
46	1 in 20
48	1 in 16
49	1 in 12

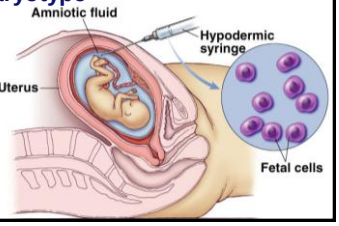


Rate of miscarriage due to amniocentesis:
- 1970s data
  0.5%, or 1 in 200 pregnancies
- 2006 data
  <0.1%, or 1 in 1600 pregnancies

Genetic testing

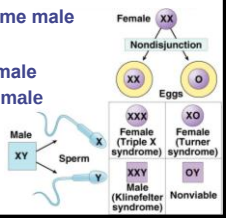
- Amniocentesis in 2nd trimester
  - sample of embryo cells
  - stain & photograph chromosomes
- Analysis of karyotype





Sex chromosomes abnormalities

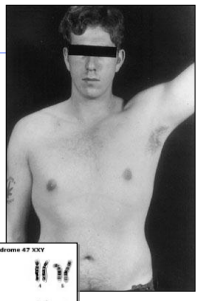
- Human development more tolerant of wrong numbers in sex chromosome
- But produces a variety of distinct syndromes in humans
  - XXY = Klinefelter's syndrome male
  - XXX = Trisomy X female
  - XYY = Jacob's syndrome male
  - XO = Turner syndrome female

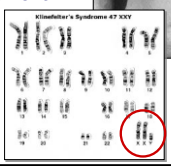


AP Biology

Klinefelter's syndrome

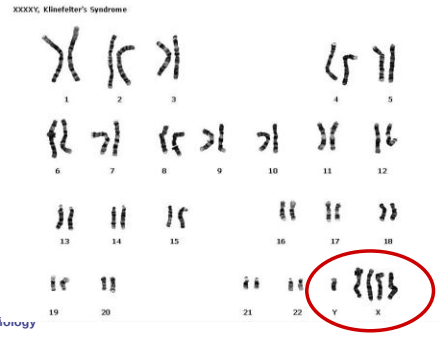
- XXY male
  - one in every 2000 live births
  - have male sex organs, but are sterile
  - feminine characteristics
    - some breast development
    - lack of facial hair
  - tall
  - normal intelligence





AP Biology

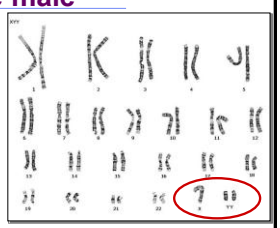
Klinefelter's syndrome



AP Biology

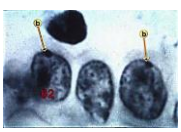
Jacob's syndrome male

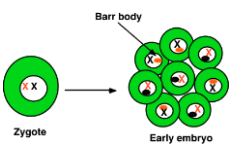
- XYY Males
  - 1 in 1000 live male births
  - extra Y chromosome
  - slightly taller than average
  - more active
  - normal intelligence, slight learning disabilities
  - delayed emotional maturity
  - normal sexual development



Trisomy X

- XXX
  - 1 in every 2000 live births
  - produces healthy females
    - Why?
    - Barr bodies
      - all but one X chromosome is inactivated

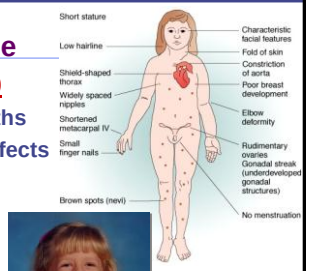




AP Biology

Turner syndrome

- M onosomy X or X0
  - 1 in every 5000 births
  - varied degree of effects
  - webbed neck
  - short stature
  - sterile



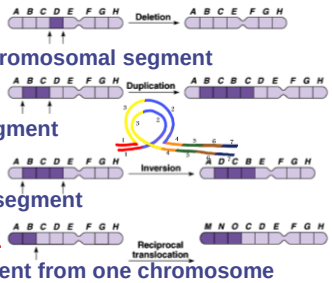
Changes in chromosome structure

error of replication

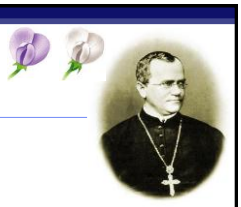
- deletion
  - loss of a chromosomal segment
- duplication
  - repeat a segment

error of crossing over

- inversion
  - reverses a segment
- translocation
  - move segment from one chromosome to another



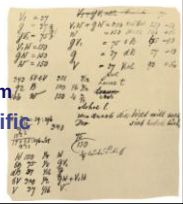
Genetics & The Work of Mendel



2006-2007

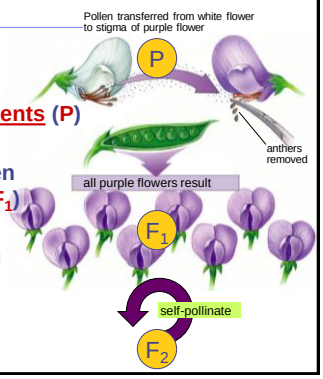
Gregor Mendel

- Modern genetics began in the mid-1800s in an abbey garden, where a monk named Gregor Mendel documented inheritance in peas
  - used experimental method
  - used quantitative analysis
    - collected data & counted them
  - excellent example of scientific method



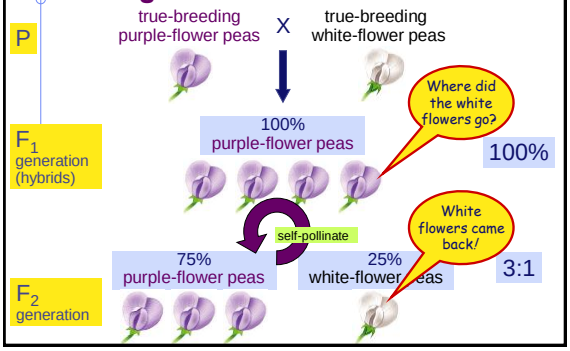
Mendel's work

- Bred pea plants
  - cross-pollinate true breeding parents (P)
    - P = parental
  - raised seed & then observed traits (F_1)
    - F = filial
  - allowed offspring to self-pollinate & observed next generation (F_2)



Mendel collected data for 7 pea traits

Looking closer at Mendel's work

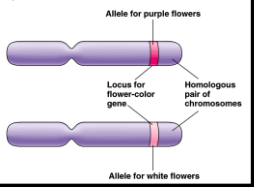


What did Mendel's findings mean?

- Traits come in alternative versions
  - purple vs. white flower color
  - alleles
    - different alleles vary in the sequence of nucleotides at the specific locus of a gene
      - some difference in sequence of A, T, C, G

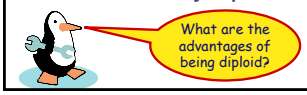
purple-flower allele & white-flower allele are two DNA variations at flower-color locus

different versions of gene at same location on homologous chromosomes



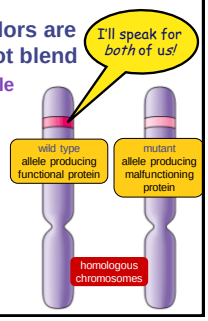
Traits are inherited as discrete units

- For each characteristic, an organism inherits 2 alleles, 1 from each parent
  - diploid organism
    - inherits 2 sets of chromosomes, 1 from each parent
    - homologous chromosomes
    - like having 2 editions of encyclopedia
      - Encyclopedia Britannica
      - Encyclopedia Americana



What did Mendel's findings mean?

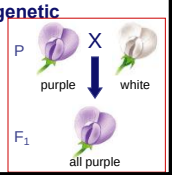
- Some traits mask others
  - purple & white flower colors are separate traits that do not blend
    - purple x white ≠ light purple
    - purple masked white
  - dominant allele
    - functional protein
    - masks other alleles
  - recessive allele
    - allele makes a malfunctioning protein



Genotype vs. phenotype

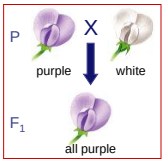
- Difference between how an organism "looks" & its genetics
  - phenotype
    - description of an organism's trait
    - the "physical"
  - genotype
    - description of an organism's genetic makeup

Explain Mendel's results using
…dominant & recessive
…phenotype & genotype



Making crosses

- Can represent alleles as letters
  - flower color alleles → **P** or ***p***
  - true-breeding purple-flower peas → **PP**
  - true-breeding white-flower peas → ***pp***

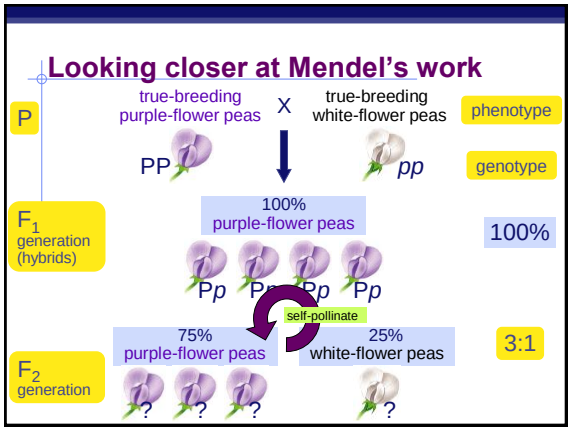


PP x *pp*

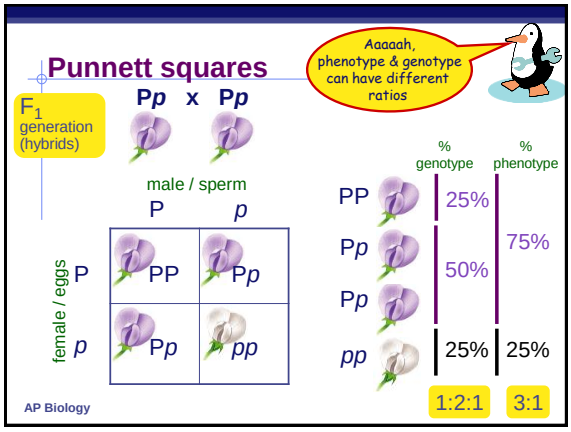
↓

Pp

Looking closer at Mendel's work

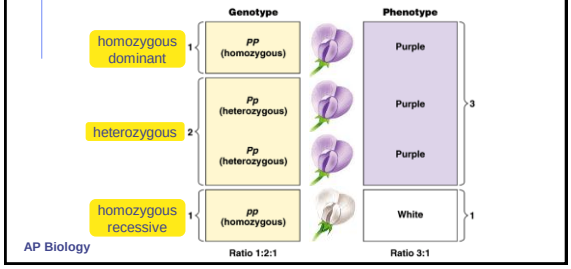


Punnett squares



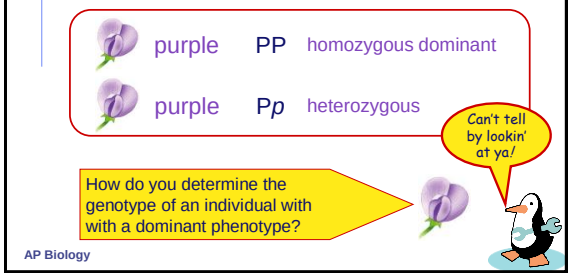
Genotypes

- **Homozygous** = ***same*** **alleles = PP, *pp***
- **Heterozygous** = ***different*** **alleles = P*p***



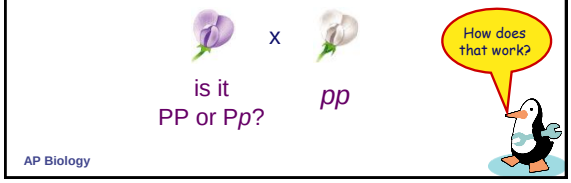
Phenotype vs. genotype

- **2 organisms can have the same phenotype but have different genotypes**

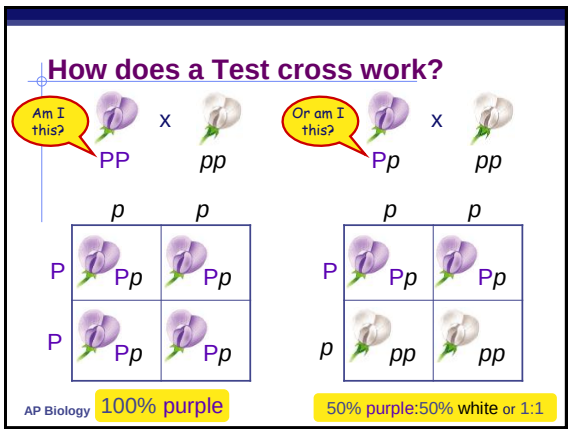


Test cross

- **Breed the dominant phenotype — the unknown genotype — with a homozygous recessive (*pp*) to determine the identity of the unknown allele**

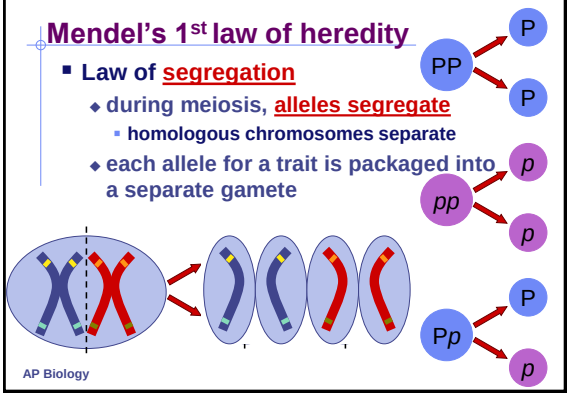


How does a Test cross work?



Mendel's 1st law of heredity

- Law of segregation
  - during meiosis, alleles segregate
    - homologous chromosomes separate
  - each allele for a trait is packaged into a separate gamete

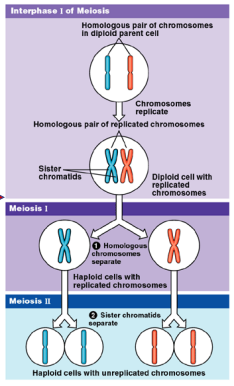


Law of Segregation

- Which stage of meiosis creates the law of segregation?

Metaphase 1

Whoa! And Mendel didn't even know DNA or genes existed!

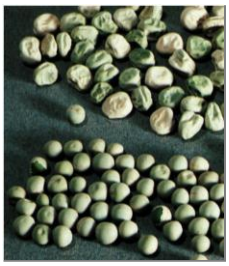


Monohybrid cross

- Some of Mendel's experiments followed the inheritance of single characters
  - flower color
  - seed color
  - monohybrid crosses

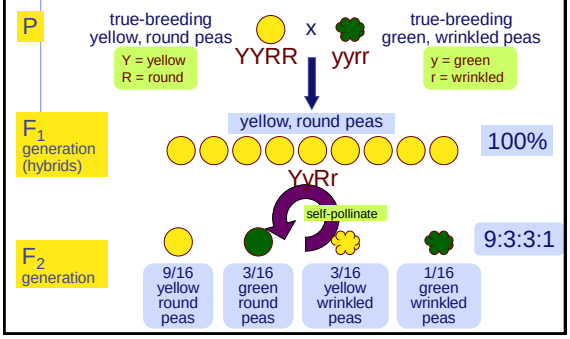
Dihybrid cross

- Other of Mendel's experiments followed the inheritance of 2 different characters
  - seed color and seed shape
  - dihybrid crosses



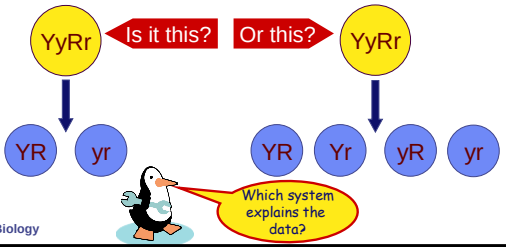
Mendel was working out many of the genetic rules!

Dihybrid cross



What's going on here?

- If genes are on different chromosomes…
  - how do they assort in the gametes?
  - together or independently?



Is this the way it works?

YyRr x YyRr

or

	YR	yr
YR	YYRR	YyRr
yr	YyRr	yyrr

Well, that's *NOT* right!

9/16 yellow round
3/16 green round
3/16 yellow wrinkled
1/16 green wrinkled

Dihybrid cross

YyRr x YyRr

or

	YR	Yr	yR	yr
YR	YYRR	YYRr	YyRR	YyRr
Yr	YYRr	YYrr	YyRr	Yyrr
yR	YyRR	YyRr	yyRR	yyRr
yr	YyRr	Yyrr	yyRr	yyrr

BINGO!

9/16 yellow round
3/16 green round
3/16 yellow wrinkled
1/16 green wrinkled

Mendel's 2nd law of heredity

Can you think of an exception to this?

- Law of independent assortment
  - different loci (genes) separate into gametes independently
    - non-homologous chromosomes align independently
    - classes of gametes produced in equal amounts
      - YR = Yr = yR = yr
    - only true for genes on separate chromosomes or on same chromosome but so far apart that crossing over happens frequently

yellow
green
round
wrinkled

YyRr

Yr Yr yR yR YR YR yr yr

1 : 1 : 1 : 1

Law of Independent Assortment

- Which stage of meiosis creates the law of independent assortment?

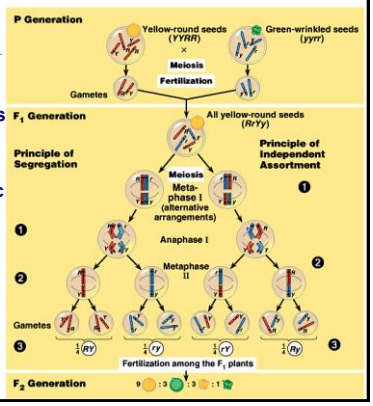
Metaphase 1

Remember Mendel didn't even know DNA —or genes— existed!

EXCEPTION
- If genes are on same chromosome & close together
  - will usually be inherited together
  - rarely crossover separately
  - "linked"

The chromosomal basis of Mendel's laws…

Trace the genetic events through meiosis, gamete formation & fertilization to offspring



Review: Mendel's laws of heredity

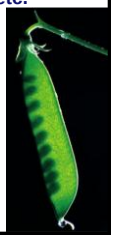
- Law of segregation
  - monohybrid cross
    - single trait
  - each allele segregates into separate gametes
    - established by Metaphase 1
- Law of independent assortment
  - dihybrid (or more) cross
    - 2 or more traits
  - genes on separate chromosomes assort into gametes independently
    - established by Metaphase 1

EXCEPTION
- linked genes

metaphase1

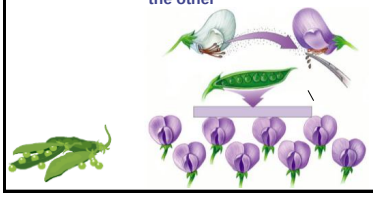
Mendel chose peas wisely

- Pea plants are good for genetic research
  - available in many varieties with distinct heritable features with different variations
    - flower color, seed color, seed shape, etc.
  - Mendel had strict control over which plants mated with which
    - each pea plant has male & female structures
    - pea plants can self-fertilize
    - Mendel could also cross-pollinate plants: moving pollen from one plant to another



Mendel chose peas luckily

- Pea plants are good for genetic research
  - relatively simple genetically
    - most characters are controlled by a single gene with each gene having only 2 alleles,
      - one completely dominant over the other



Beyond Mendel's Laws of Inheritance

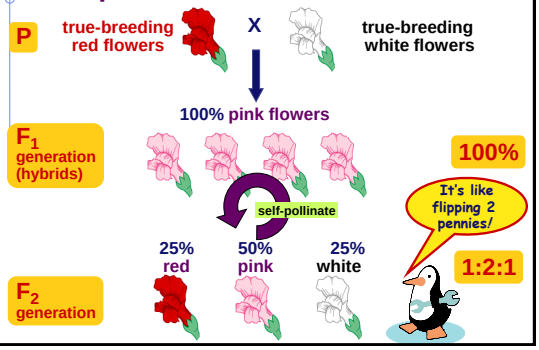
Extending Mendelian genetics

- Mendel worked with a simple system
  - peas are genetically simple
  - most traits are controlled by a single gene
  - each gene has only 2 alleles, 1 of which is completely dominant to the other
- The relationship between genotype & phenotype is rarely that simple

Incomplete dominance

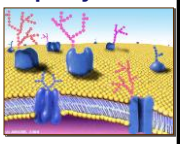
- Heterozygote shows an intermediate, blended phenotype
  - example:
    - RR = red flowers →RR
    - rr = white flowers →WW
    - Rr = pink flowers →RW
      - make 50% less color

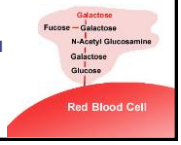
Incomplete dominance



Co-dominance

- 2 alleles affect the phenotype equally & separately
  - not blended phenotype
  - human ABO blood groups
  - 3 alleles
    - I^A, I^B, *i*
    - I^A & I^B alleles are co-dominant
      - glycoprotein antigens on RBC
      - I^AI^B = both antigens are produced
    - *i* allele recessive to both



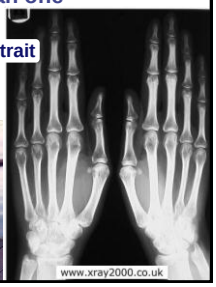


Genetics of Blood type

pheno-type	genotype	antigen on RBC	antibodies in blood	donation status
A		antigens on surface of RBC	antibodies	___
B		antigens on surface of RBC	antibodies	___
AB		antigens on surface of RBC	antibodies	
O		on surface of RBC	antibodies	

Pleiotropy

- Most genes are pleiotropic
  - one gene affects more than one phenotypic character
    - 1 gene affects more than 1 trait
    - dwarfism (achondroplasia)
    - gigantism (acromegaly)



Acromegaly: André the Giant

Inheritance pattern of Achondroplasia

Aa x aa

dominant inheritance

	a	a
A	Aa dwarf	Aa dwarf
a	aa	aa

50% dwarf:50% normal or 1:1

Aa x Aa

	A	a
A	AA lethal	Aa
a	Aa	aa

67% dwarf:33% normal or 2:1

Epistasis

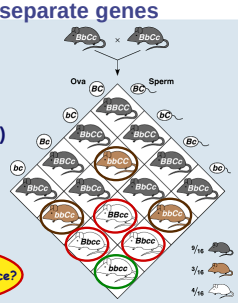
- One *gene* completely masks another *gene*
  - coat color in mice = 2 separate genes
    - C,c: pigment (C) or no pigment (*c*)
    - B,b: more pigment (black=B) or less (brown=b)
    - *cc* = albino, no matter B allele
    - 9:3:3:1 becomes 9:3:4

B_C_

*bbC_*

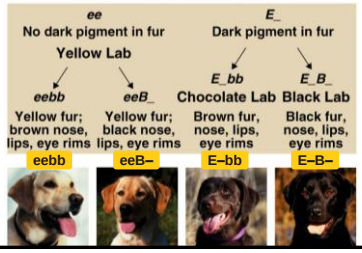
__cc

How would you know that difference wasn't random chance? Chi-square test!



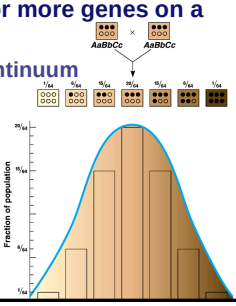
Epistasis in Labrador retrievers

- 2 genes: (E,e) & (B,b)
  - pigment (E) or no pigment (e)
  - pigment concentration: black (B) to brown (b)



Polygenic inheritance

- Some phenotypes determined by additive effects of 2 or more genes on a single character
  - phenotypes on a continuum
  - human traits
    - skin color
    - height
    - weight
    - intelligence
    - behaviors



Skin color: Albinism

Johnny & Edgar Winter

- However albinism can be inherited as a single gene trait
  - aa = albino

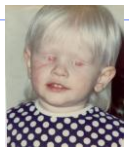
albino Africans

melanin = universal brown color

tyrosine —enzyme→ melanin —albinism

OCA1 albino

Bianca Knowlton

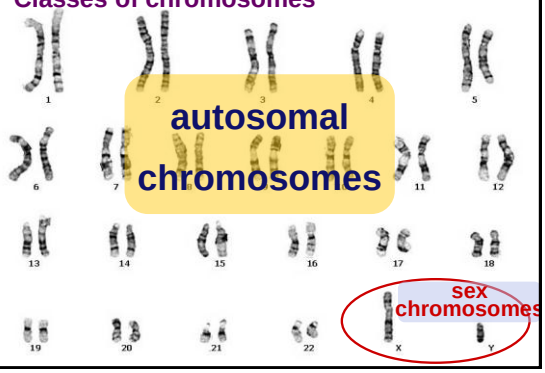


Sex linked traits

1910 | 1933

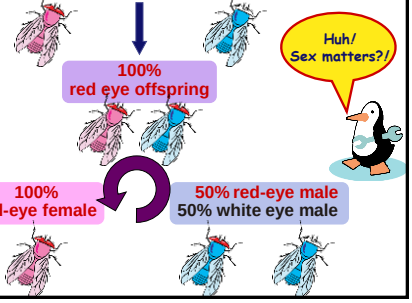
- Genes are on sex chromosomes
  - as opposed to autosomal chromosomes
  - first discovered by T.H. Morgan at Columbia U.
  - *Drosophila* breeding
    - good genetic subject
      - prolific
      - 2 week generations
      - 4 pairs of chromosomes
      - XX=female, XY=male

Classes of chromosomes



Discovery of sex linkage

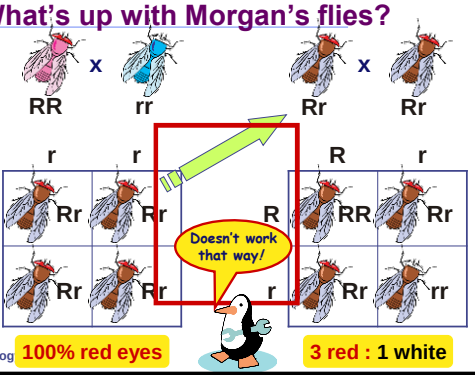
P: true-breeding red-eye female x true-breeding white-eye male



F_1 generation (hybrids): 100% red eye offspring

F_2 generation: 100% red-eye female; 50% red-eye male, 50% white eye male

What's up with Morgan's flies?



AP Biolog 100% red eyes

3 red : 1 white

Genetics of Sex

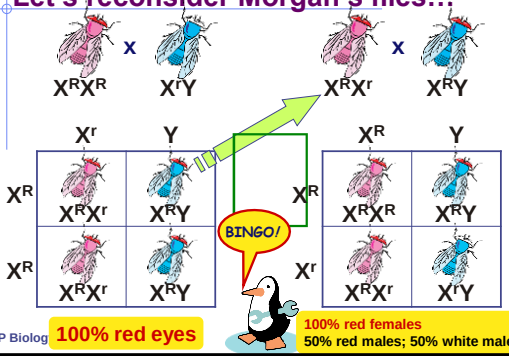
- In humans & other mammals, there are 2 sex chromosomes: X & Y
  - 2 X chromosomes
    - develop as a female: XX
    - gene redundancy, like autosomal chromosomes
  - an X & Y chromosome
    - develop as a male: XY
    - no redundancy

	X	Y
X	XX	XY
X	XX	XY

AP Biology

50% female : 50% male

Let's reconsider Morgan's flies…



AP Biolog 100% red eyes

100% red females
50% red males; 50% white males

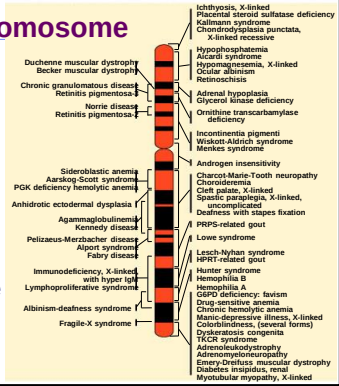
Genes on sex chromosomes

- Y chromosome
  - few genes other than SRY
    - sex-determining region
    - master regulator for maleness
    - turns on genes for production of male hormones
      - many effects = pleiotropy!
- X chromosome
  - other genes/traits beyond sex determination
    - mutations:
      - hemophilia
      - Duchenne muscular dystrophy

AP Biology

Human X chromosome

- Sex-linked
  - usually means "X-linked"
  - more than 60 diseases traced to genes on X chromosome



AP Biology

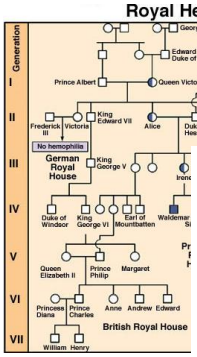
Map of Human Y chromosome?

< 30 genes on Y chromosome

- Sex-determining Region Y (SRY)
- Channel Flipping (FLP)
- Catching & Throwing (BLZ-1)
- Self confidence (BLZ-2)
  - note: not linked to ability gene
- Devotion to sports (BUD-E)
- Addiction to death & destruction movies (SAW-2)
- Air guitar (RIF)
- Scratching (ITCH-E) — linked
- Spitting (P2E) — linked
- Inability to express affection over phone (ME-2)
- Selective hearing loss (HUH)
- Total lack of recall for dates (OOPS)

AP Biology

Royal Hemophilia Pedigree



Queen Victoria and Descendants

AP Biology

Hemophilia

sex-linked recessive

X^HX^h x X^HY

male / sperm: X^H Y

female / eggs: X^H X^h

	X^H	Y
X^H	X^HX^H	X^HY
X^h	X^HX^h	X^hY

carrier disease

X^HX^h → X^H, X^h

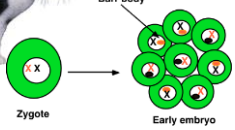
X^HY → X^H, Y

AP Biology

X-inactivation

- Female mammals inherit 2 X chromosomes
  - one X becomes inactivated during embryonic development
    - condenses into compact object = Barr body
    - which X becomes Barr body is random
      - patchwork trait = "mosaic"

tricolor cats can only be female



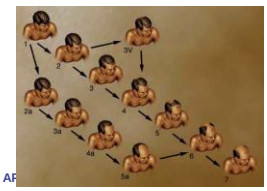
patches of black

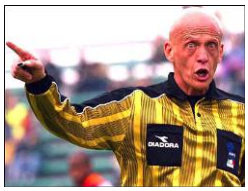
X^HX^h → X^H ●, ● X^h

patches of orange

Male pattern baldness

- Sex influenced trait
  - autosomal trait influenced by sex hormones
    - age effect as well = onset after 30 years old
  - dominant in males & recessive in females
    - B_ = bald in males; bb = bald in females





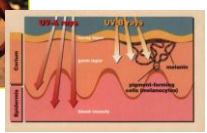
Environmental effects

- Phenotype is controlled by both environment & genes

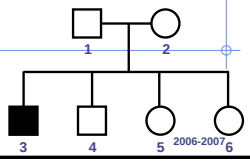
Human skin color is influenced by both genetics & environmental conditions

Color of Hydrangea flowers is influenced by soil pH

Coat color in arctic fox influenced by heat sensitive alleles



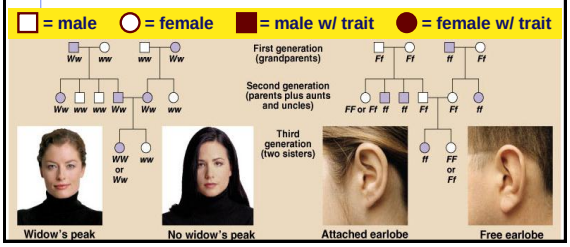
Human Genetic Diseases



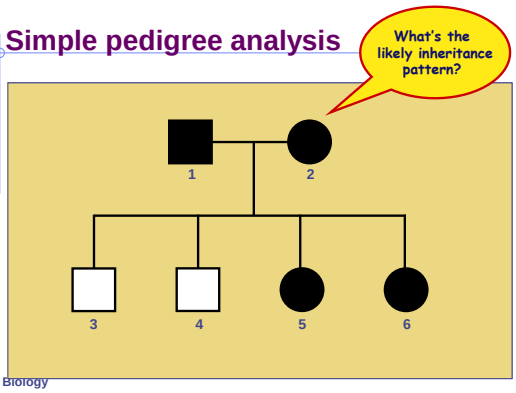
2006-2007

Pedigree analysis

- Pedigree analysis reveals Mendelian patterns in human inheritance
  - data mapped on a family tree



Simple pedigree analysis



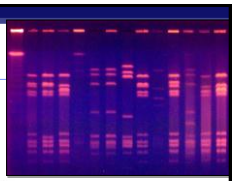
AP Biology

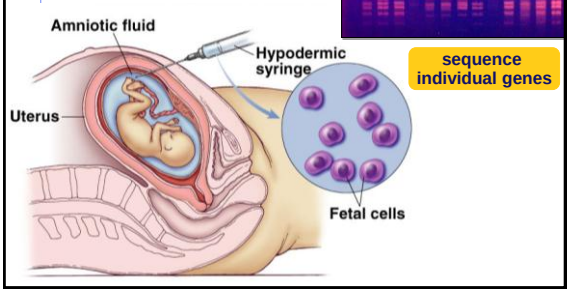
Genetic counseling

- Pedigree can help us understand the past & predict the future
- Thousands of genetic disorders are inherited as simple recessive traits
  - from benign conditions to deadly diseases
    - albinism
    - cystic fibrosis
    - Tay sachs
    - sickle cell anemia
    - PKU

AP Biology

Genetic testing





sequence individual genes

Recessive diseases

- The diseases are recessive because the allele codes for either a malfunctioning protein or no protein at all
  - Heterozygotes (Aa)
    - carriers
    - have a normal phenotype because one "normal" allele produces enough of the required protein

AP Biology

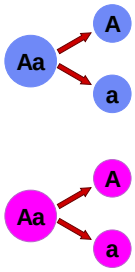
Heterozygote crosses

- Heterozygotes as carriers of recessive alleles

Aa x Aa

male / sperm

female / eggs	A	a
A	AA	Aa carrier
a	Aa carrier	aa disease



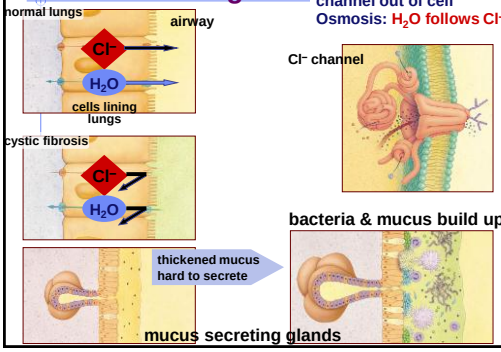
Cystic fibrosis (recessive)

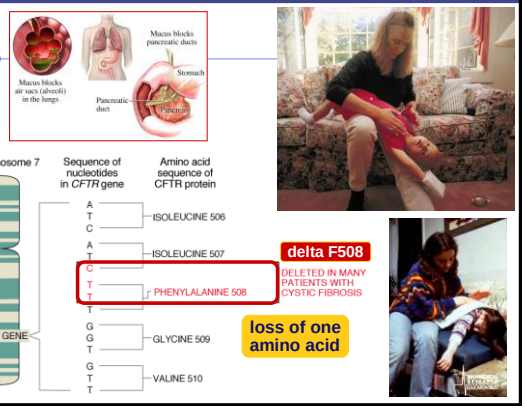

normal lung tissue

- Primarily whites of European descent
  - strikes 1 in 2500 births
    - 1 in 25 whites is a carrier (Aa)
  - normal allele codes for a membrane protein that transports Cl^- across cell membrane
    - defective or absent channels limit transport of Cl^- & H_2O across cell membrane
    - thicker & stickier mucus coats around cells
    - mucus build-up in the pancreas, lungs, digestive tract & causes bacterial infections
  - without treatment children die before 5; with treatment can live past their late 20s

Effect on Lungs

Chloride channel
transports salt through protein channel out of cell
Osmosis: H_2O follows Cl^-





Tay-Sachs (recessive)

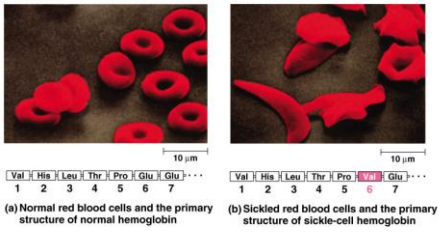
- Primarily Jews of eastern European (Ashkenazi) descent & Cajuns (Louisiana)
  - strikes 1 in 3600 births
    - 100 times greater than incidence among non-Jews
  - non-functional enzyme fails to breakdown lipids in brain cells
    - fats collect in cells destroying their function
    - symptoms begin few months after birth
    - seizures, blindness & degeneration of muscle & mental performance
    - child usually dies before 5yo

Sickle cell anemia (recessive)

- Primarily Africans
  - strikes 1 out of 400 African Americans
    - high frequency
  - caused by substitution of a single amino acid in hemoglobin
  - when oxygen levels are low, sickle-cell hemoglobin crystallizes into long rods
    - deforms red blood cells into sickle shape
    - sickling creates pleiotropic effects = cascade of other symptoms

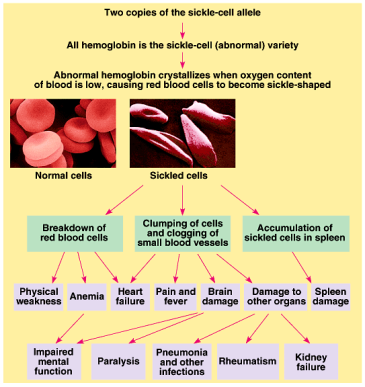
Sickle cell anemia

- Substitution of one amino acid in polypeptide chain



hydrophilic amino acid

hydrophobic amino acid



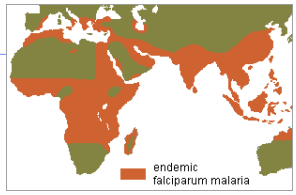
Sickle cell phenotype

- 2 alleles are codominant
  - both normal & mutant hemoglobins are synthesized in heterozygote (Aa)
  - 50% cells sickle; 50% cells normal
  - carriers usually healthy
  - sickle-cell disease triggered under blood oxygen stress
    - exercise

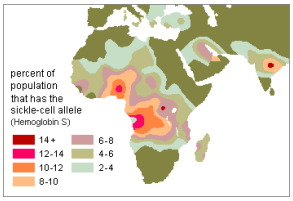
Heterozygote advantage

- Malaria
  - single-celled eukaryote parasite spends part of its life cycle in red blood cells
- In tropical Africa, where malaria is common:
  - homozygous dominant individuals die of malaria
  - homozygous recessive individuals die of sickle cell anemia
  - heterozygote carriers are relatively free of both
    - reproductive advantage
- High frequency of sickle cell allele in African Americans is vestige of African roots

Prevalence of Malaria

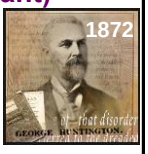


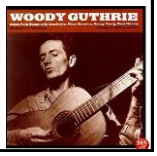
Prevalence of Sickle Cell Anemia



Huntington's chorea (dominant)

- Dominant inheritance
  - repeated mutation on end of chromosome 4
    - mutation = CAG repeats
    - glutamine amino acid repeats in protein
    - one of 1st genes to be identified
  - build up of "huntingtin" protein in brain causing cell death
    - memory loss
    - muscle tremors, jerky movements
      - "chorea"
    - starts at age 30-50
    - early death
      - 10-20 years after start





Genetics & culture

- Why do all cultures have a taboo against incest?
  - laws or cultural taboos forbidding marriages between close relatives are fairly universal
- Fairly unlikely that 2 unrelated carriers of same rare harmful recessive allele will meet & mate
  - but matings between close relatives increase risk
    - "consanguineous" (same blood) matings
  - individuals who share a recent common ancestor are more likely to carry same recessive alleles

A hidden disease reveals itself

AA x Aa

female / eggs \ male / sperm	A	A
A	AA	AA
a	Aa	Aa

Aa x Aa

female / eggs \ male / sperm	A	a
A	AA	Aa
a	Aa	aa

- increase carriers in population
- hidden disease is revealed