


Chapter 14.
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



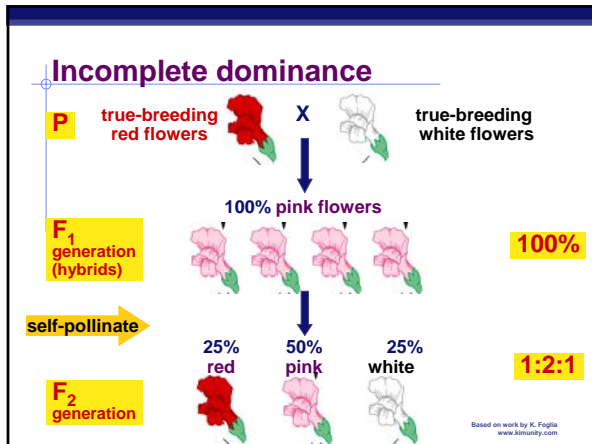
MCC BP

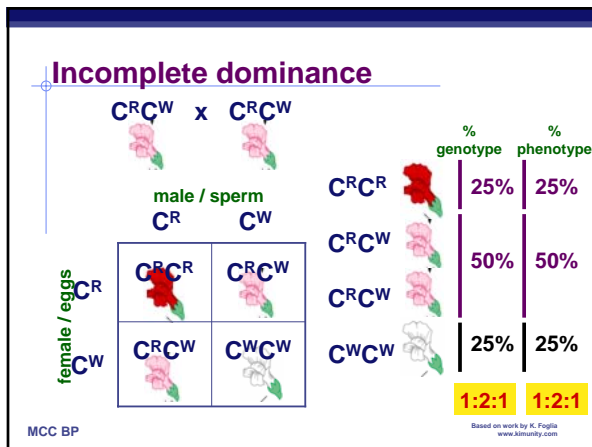
Incomplete dominance

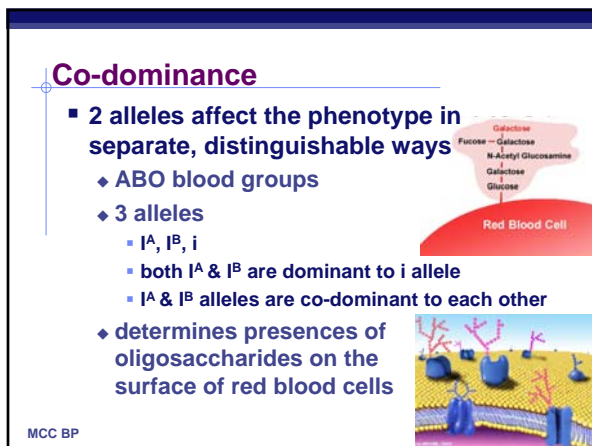
- Heterozygotes show an intermediate phenotype
 - ◆ RR = red flowers
 - ◆ rr = white flowers
 - ◆ Rr = pink flowers
 - make 50% less color



MCC BP







Blood type


genotype	phenotype	phenotype	status
I ^A I ^A I ^A i	type A	type A oligosaccharides on surface of RBC	—
I ^B I ^B I ^B i	type B	type B oligosaccharides on surface of RBC	—
I ^A I ^B	type AB	both type A & type B oligosaccharides on surface of RBC	universal recipient
ii	type O	no oligosaccharides on surface of RBC	universal donor

MCC BP Based on work by K. Foglia
www.kimunity.com

Blood compatibility

1901 | 1930

- Matching compatible blood groups
 - ◆ critical for blood transfusions
- A person produces antibodies against oligosaccharides in foreign blood
 - ◆ wrong blood type
 - donor's blood has A or B oligosaccharide that is foreign to recipient
 - antibodies in recipient's blood bind to foreign molecules
 - cause donated blood cells to clump together
 - can kill the recipient



Karl Landsteiner
(1868-1943)

MCC BP Based on work by K. Foglia
www.kimunity.com

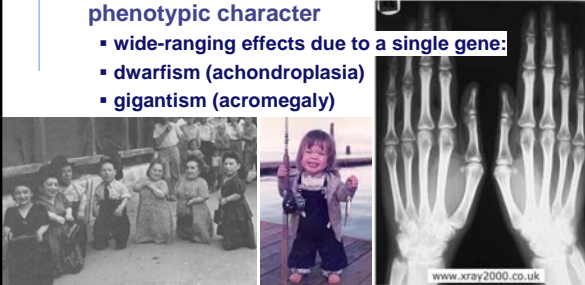
Blood donation

(a) Phenotype (blood group)	(b) Genotypes (see p.258)	(c) Antibodies present in blood serum	(d) Results from adding red blood cells from groups below to serum from groups at left
			A B AB O
A	I ^A I ^A or I ^A i	Anti-B	
B	I ^B I ^B or I ^B i	Anti-A	
AB	I ^A I ^B	—	
O	ii	Anti-A Anti-B	

MCC BP Based on work by K. Foglia
www.kimunity.com

Pleiotropy

- Most genes are **pleiotropic**
 - ◆ one gene affects more than one phenotypic character
 - wide-ranging effects due to a single gene:
 - dwarfism (achondroplasia)
 - gigantism (acromegaly)



www.xray2000.co.uk

Acromegaly: André the Giant



MCC BP

Based on work by K. Foglia
www.kimunity.com

Pleiotropy

- It is not surprising that a gene can affect a number of organism's characteristics
 - ◆ consider the intricate molecular & cellular interactions responsible for an organism's development
 - cystic fibrosis
 - ◆ mucus build up in many organs
 - sickle cell anemia
 - ◆ sickling of blood cells

MCC BP

Based on work by K. Foglia
www.kimunity.com

Epistasis

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

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

Epistasis in Labrador retrievers

- 2 genes: E & B
 - pigment (E) or no pigment (e)
 - how dark pigment will be: black (B) to brown (b)

MCC BP

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
 - eye color
 - intelligence
 - behaviors

MCC BP

Albinism

Johnny & Edgar Winter

albinos Africans

MCC BP

Nature vs. nurture

- 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

It all started with a fly...

- Chromosome theory of inheritance
 - experimental evidence from improved microscopy & animal breeding led us to a better understanding of chromosomes & genes beyond Mendel
 - Drosophila* studies


A. H. Sturtevant in the *Drosophila* stockroom at Columbia University

MCC BP

1910 | 1933


Thomas Hunt Morgan

- embryologist at Columbia University
 - ◆ 1st to associate a specific gene with a specific chromosome
 - ◆ *Drosophila* breeding
 - prolific
 - 2 week generations
 - 4 pairs of chromosomes
 - XX=female, XY=male



Morgan's first mutant...

- Wild type fly = red eyes
- Morgan discovered a mutant white-eyed male
 - ◆ traced the gene for eye color to a specific chromosome



MCC BP Based on work by K. Foglia
www.kofology.com

Discovery of sex linkage

red eye female × white eye male

↓

all red eye offspring

↓

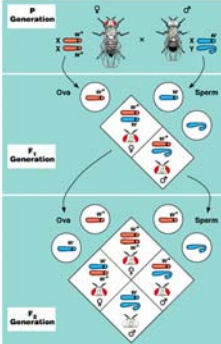
75% red eye female

25% white eye male

↓


How is this possible?

Sex-linked trait!



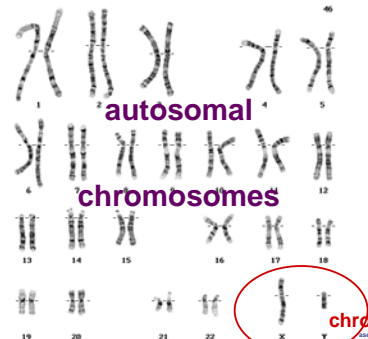
Sex-linked traits

- Although differences between women & men are many, the chromosomal basis of sex is rather simple
- In humans & other mammals, there are 2 sex chromosomes: X & Y
 - ♦ 2 X chromosomes develops as a female: XX
 - redundancy
 - ♦ an X & Y chromosome develops as a male: XY
 - no redundancy



MCC BP www.kimunity.com

Sex chromosomes



MCC BP Based on work by K. Foglia
www.kimunity.com

Genes on sex chromosomes

- Y chromosome
 - ♦ SRY: sex-determining region
 - master regulator for maleness
 - turns on genes for production of male hormones
 - ♦ pleiotropy!
- X chromosome
 - ♦ other traits beyond sex determination
 - hemophilia
 - Duchenne muscular dystrophy
 - color-blind

MCC BP Based on work by K. Foglia
www.kimunity.com

Human X chromosome

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

MCC BP

Map of Human Y chromosome?

- < 30 genes on Y chromosome

MCC BP

Sex-linked traits

sex-linked recessive

male / sperm: X^H and Y

female / eggs: X^H and X^h

$X^H X^H$	$X^H Y$
$X^H X^h$	$X^h Y$

MCC BP

Based on work by K. Foglia
www.kimunity.com

Sex-linked traits summary

- **X-linked**
 - ◆ follow the X chromosomes
 - ◆ males get their X from their mother
 - ◆ trait is never passed from father to son
- **Y-linked**
 - ◆ very few traits
 - ◆ only 26 genes
 - ◆ trait is only passed from father to son
 - ◆ females cannot inherit trait

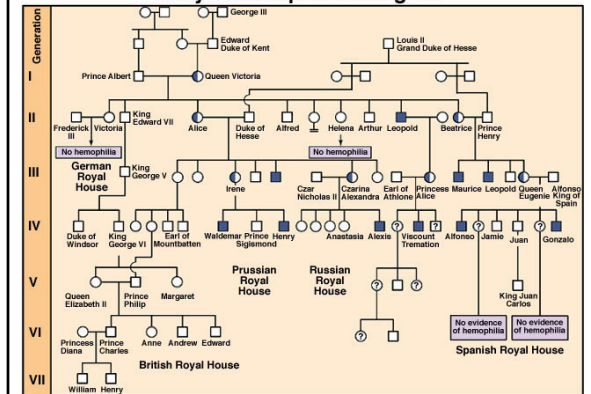
MCC BP

Based on work by K. Foglia
www.kimunity.com

Queen Victoria and Descendants



Royal Hemophilia Pedigree



X-inactivation

- Female mammals inherit two X chromosomes
 - one X becomes inactivated during embryonic development
 - condenses into compact object = Barr body

MCC BP

X-inactivation & tortoise shell cat

- 2 different cell lines in cat

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

M

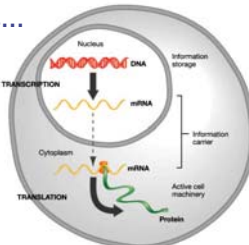
Mechanisms of inheritance

- What causes the differences in alleles of a trait?
 - yellow vs. green color
 - smooth vs. wrinkled seeds
 - dark vs. light skin
 - Tay Sachs disease vs. no disease
 - Sickle cell anemia vs. no disease

MCC BP Based on work by K. Foglia
www.kimunity.com

Mechanisms of inheritance




- What causes dominance vs. recessive?
 - genes code for polypeptides
 - polypeptides are processed into proteins
 - proteins function as...
 - enzymes
 - structural proteins
 - hormones



MCC BP

How does dominance work: enzyme




█ = allele coding for functional enzyme █ = allele coding for non-functional enzyme

-  = 50% functional enzyme
 - sufficient enzyme present
 - normal trait is exhibited
 - NORMAL** trait is DOMINANT→ **Aa** carrier
-  = 100% non-functional enzyme
 - normal trait is not exhibited→ **aa**
-  = 100% functional enzyme
 - normal trait is exhibited→ **AA**

MCC BP Based on work by K. Foglia
www.kimunity.com

How does dominance work: structure

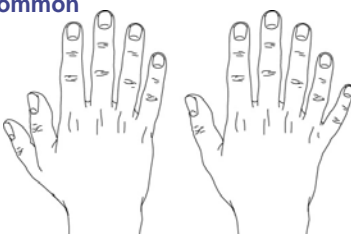
█ = allele coding for functional structural protein █ = allele coding for non-functional structural protein

-  = 50% functional structure
 - 50% proteins malformed
 - normal trait is not exhibited
 - **MUTANT** trait is **DOMINANT**Aa
-  = 100% non-functional structure
 - normal trait is not exhibitedAA
-  = 100% functional structure
 - normal trait is exhibitedaa

MCC BP Based on work by K. Foglia
www.kimunity.com

Prevalence of dominance

- Because an allele is dominant does **not** mean...
 - ◆ it is better
 - ◆ it is more common



Polydactyly:
dominant allele

MCC BP

Polydactyly



individuals are born with extra fingers or toes

dominant to the recessive allele for 5 digits

recessive allele far more common than dominant

- 399 individuals out of 400 have only 5 digits
- most people are homozygous recessive (aa)



