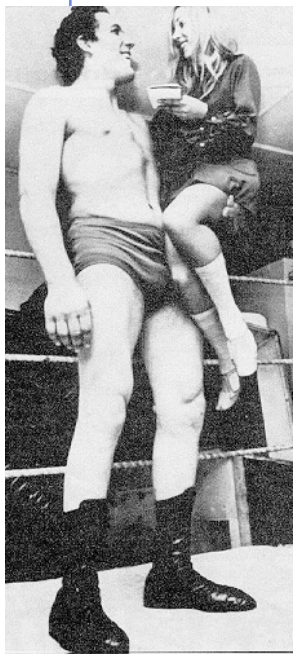
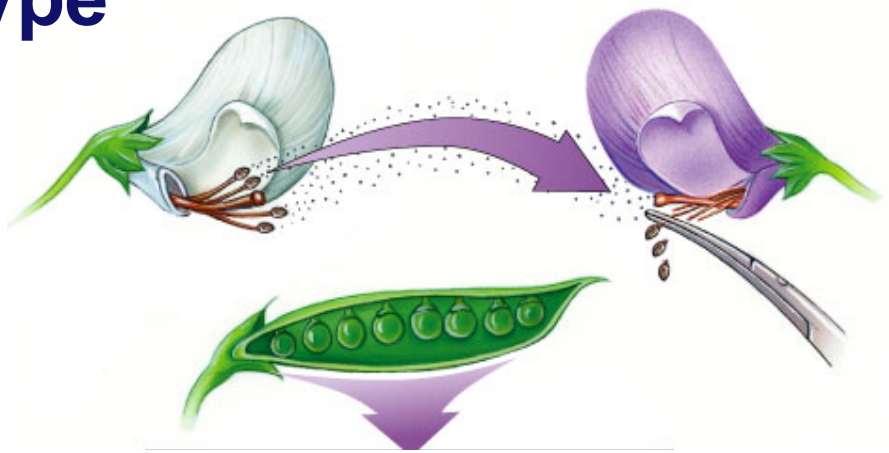
Beyond Mendel's Laws of Inheritance



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

P

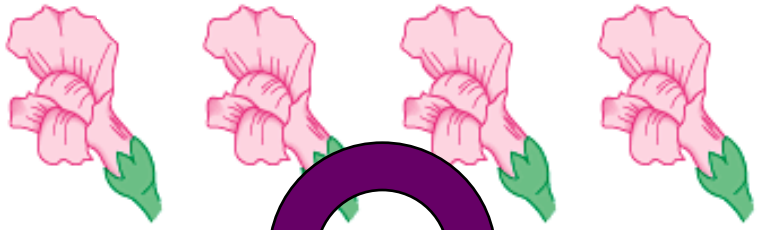
true-breeding red flowers

X

true-breeding white flowers

100% pink flowers

F_1 generation (hybrids)



self-pollinate

F_2 generation

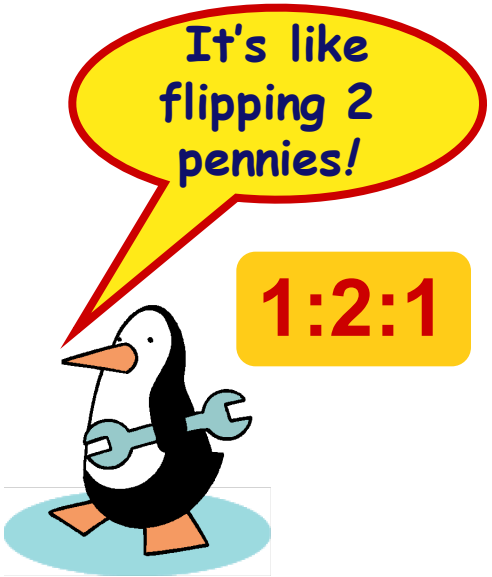
25% red

50% pink

25% white

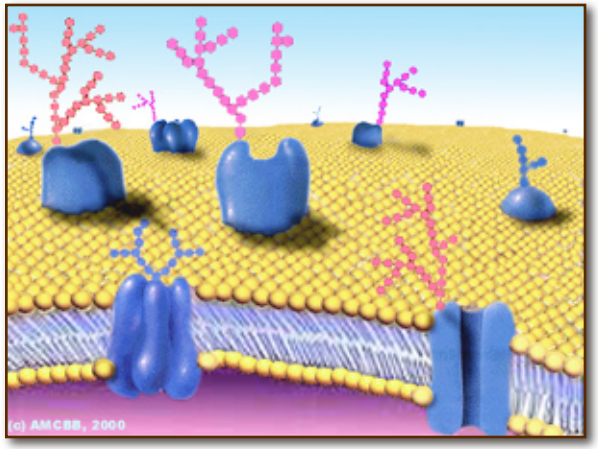
100%

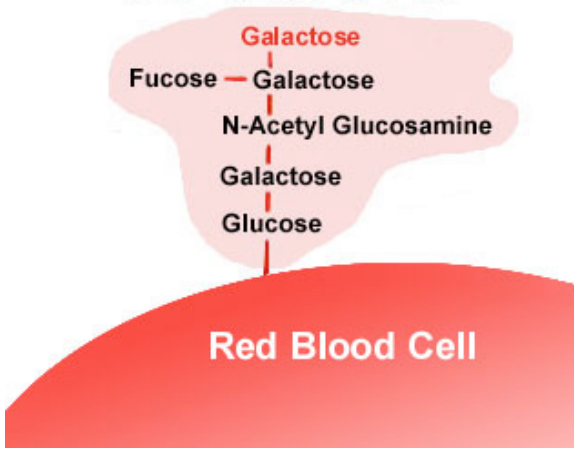
1:2:1



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





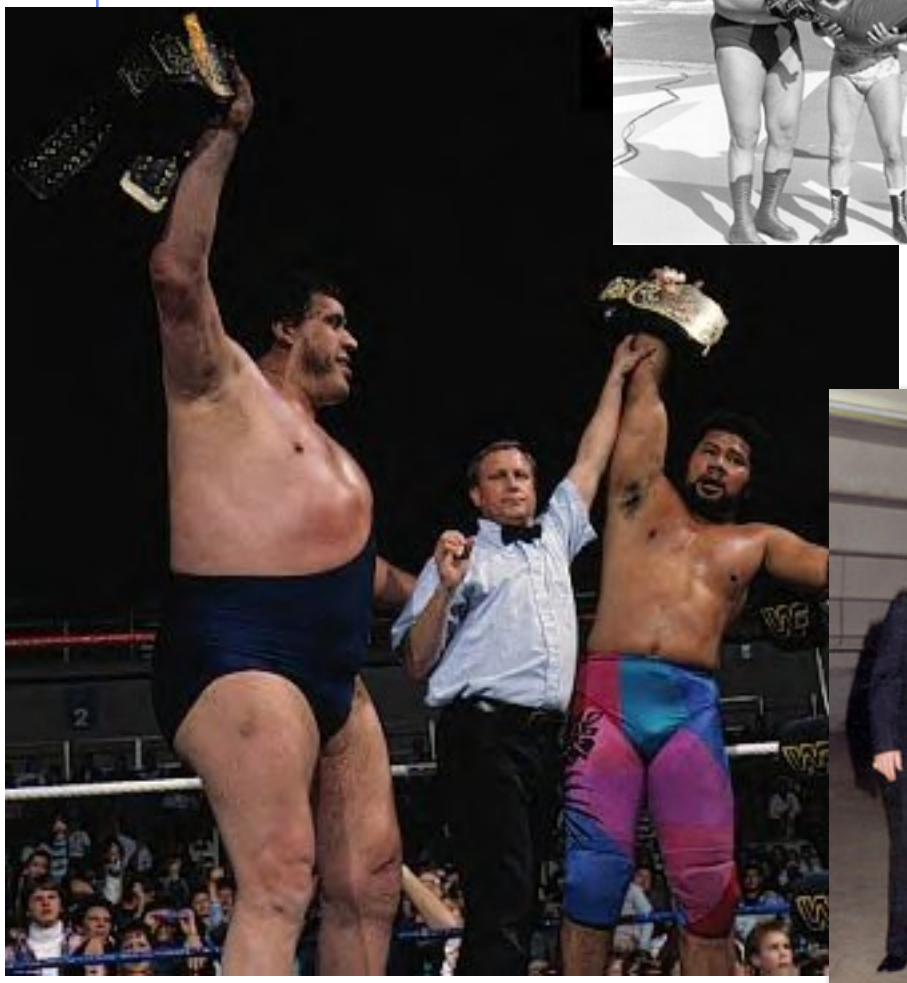
Genetics of Blood type

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

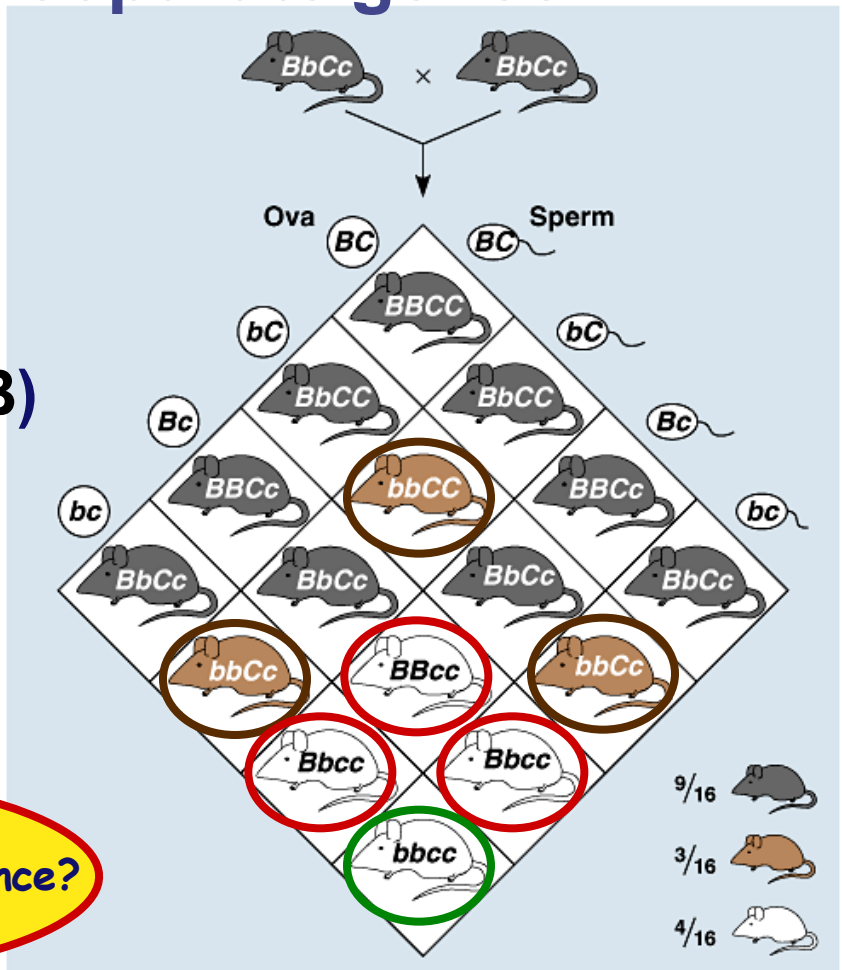
Epistasis

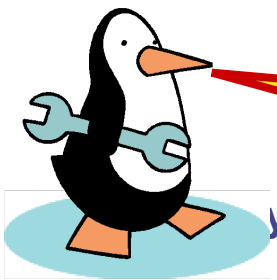
- One *gene* completely masks another *gene*
  - coat color in mice = 2 separate genes
    - C,c:
      pigment (C) or
      no pigment (*c*)
    - B,b:
      more pigment (black=B)
      or less (brown=b)
    - *cc* = albino,
      no matter B allele
    - 9:3:3:1 becomes 9:3:4

B_C_

bbC_

_ _cc

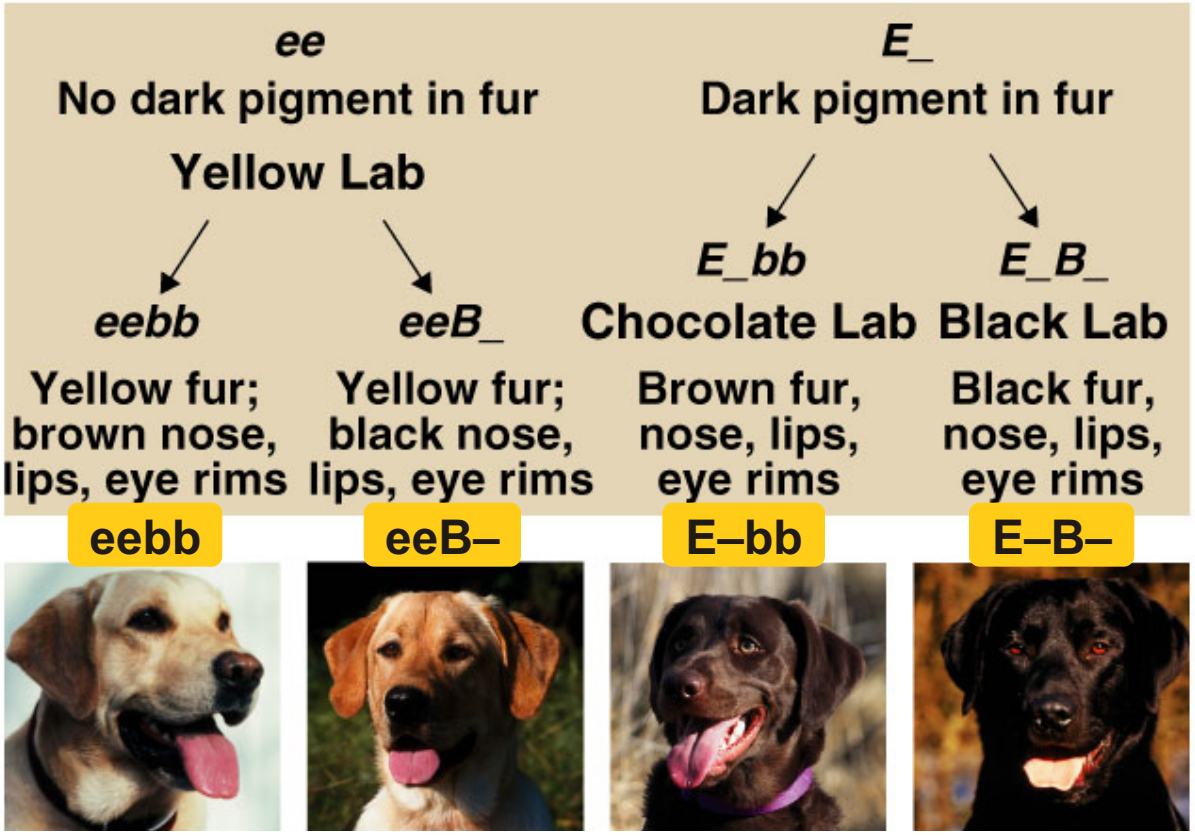




How would you know that difference wasn't random chance? Chi-square test!

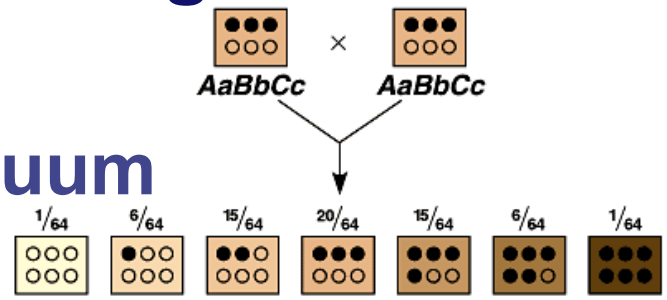
Epistasis in Labrador retrievers

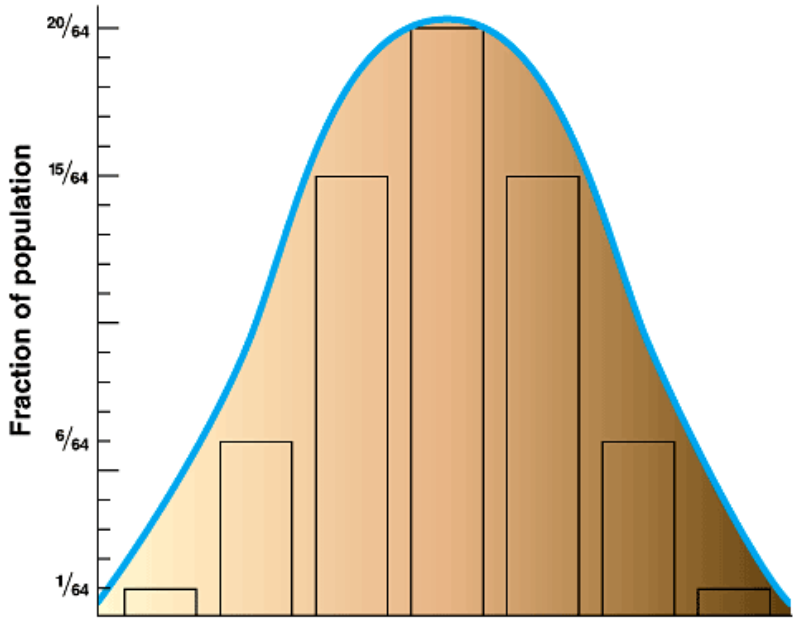
- 2 genes: (E,e) & (B,b)
  - pigment (E) or no pigment (e)
  - pigment concentration: black (B) to brown (b)



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

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

albino Africans

melanin = universal brown color

tyrosine → enzyme → melanin

albinism

Johnny & Edgar Winter

OCA1 albino

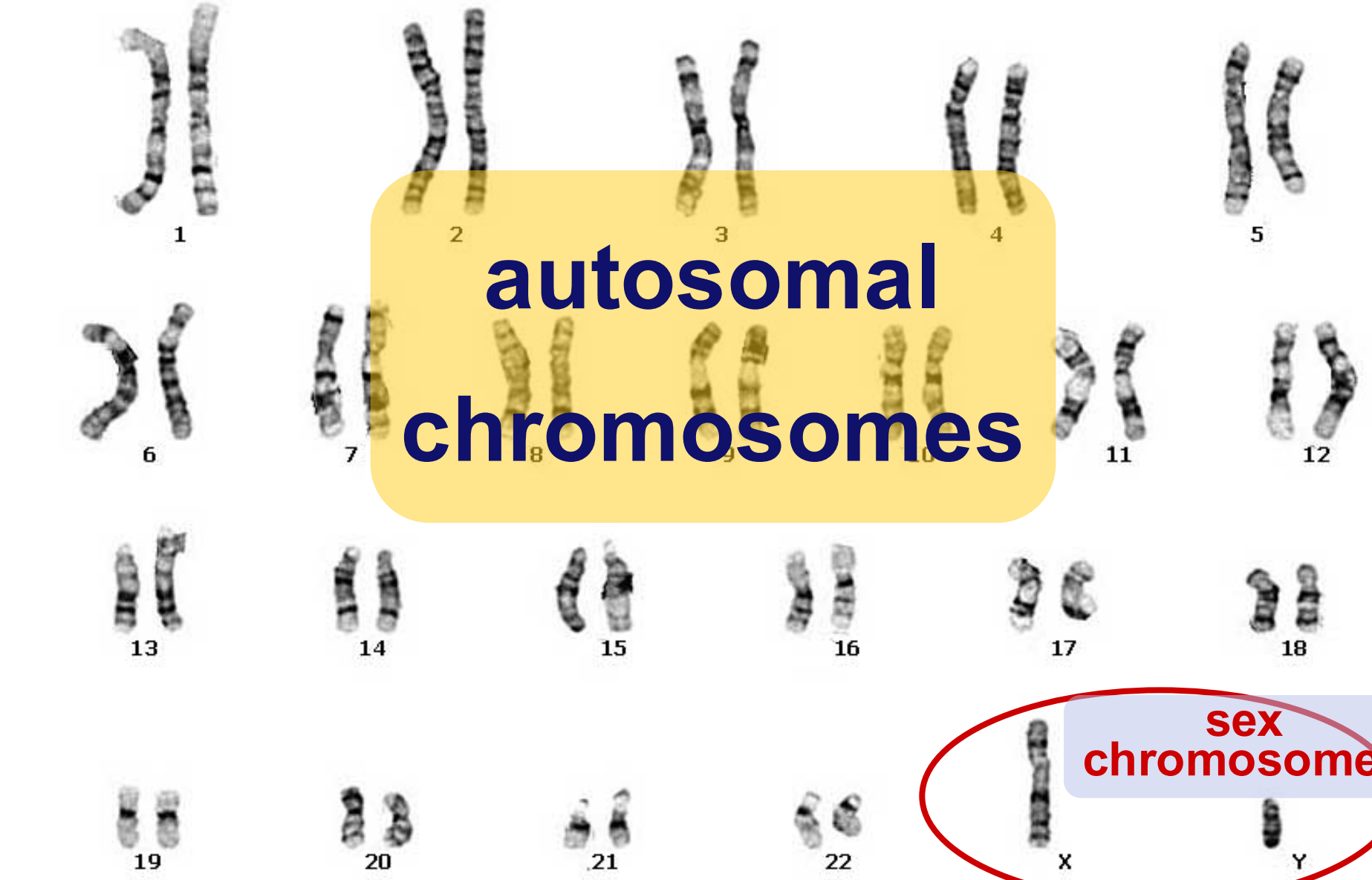
Bianca Knowlton

1910 | 1933

Sex linked traits

- 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



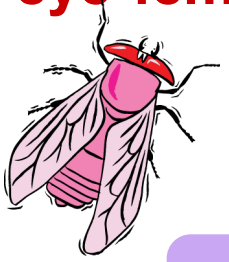
autosomal chromosomes

sex chromosomes

Discovery of sex linkage

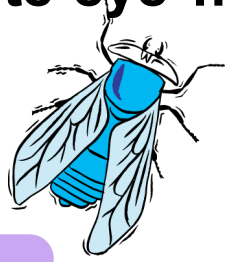
P

true-breeding red-eye female



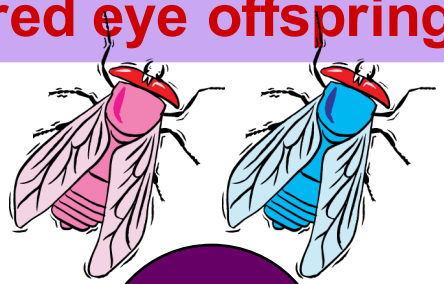
x

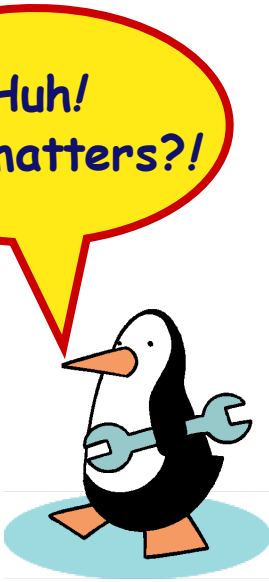
true-breeding white-eye male



F_1 generation (hybrids)

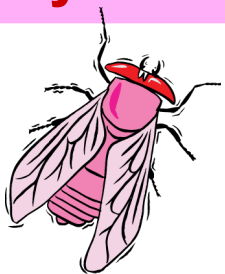
100% red eye offspring



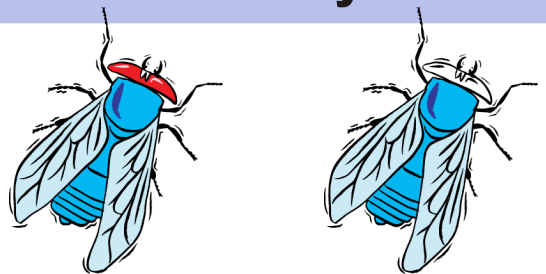


F_2 generation

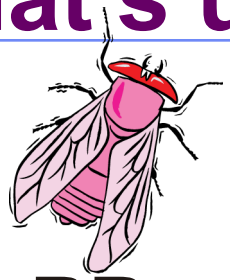
100% red-eye female



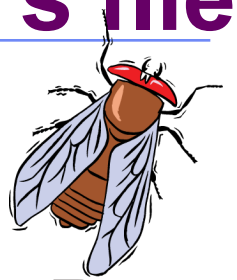
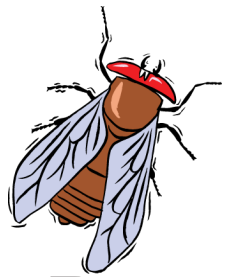
50% red-eye male
50% white eye male



What's up with Morgan's flies?



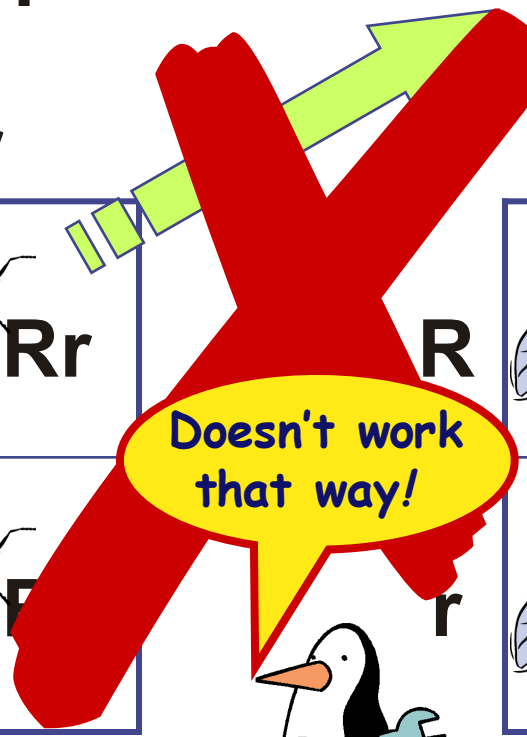

RR x rr

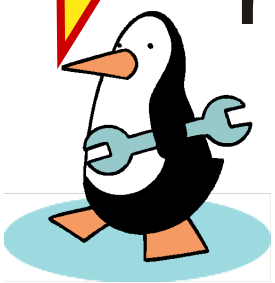



Rr x Rr

	r	r
R	Rr	Rr
R	Rr	Rr

	R	r
R	RR	Rr
r	Rr	rr



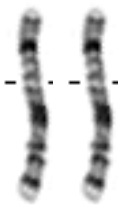


100% red eyes

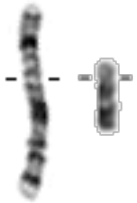
3 red : 1 white

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

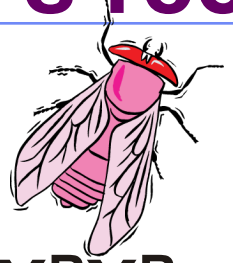


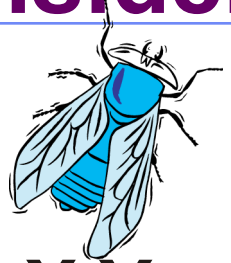
    - develop as a male: XY
    - no redundancy

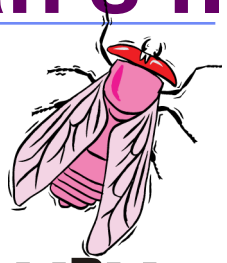
	X	Y
X	XX	XY
X	XX	XY

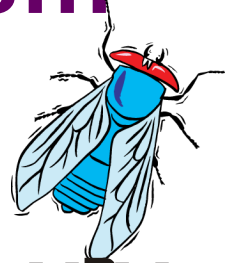
50% female : 50% male

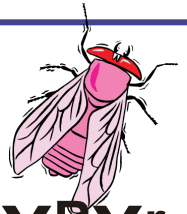
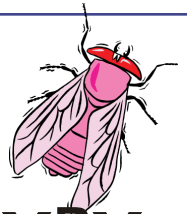
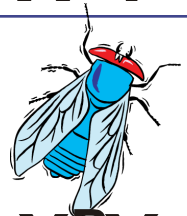
Let's reconsider Morgan's flies…

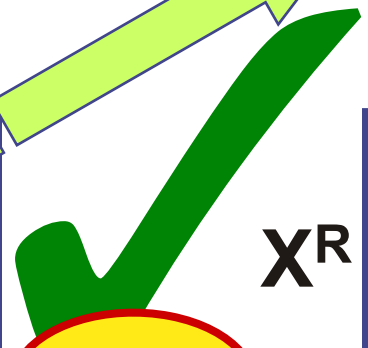


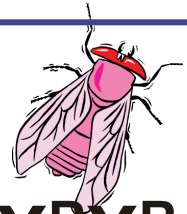
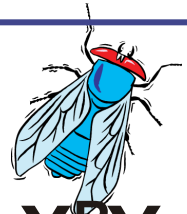
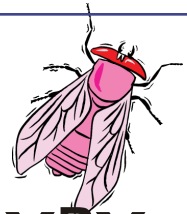
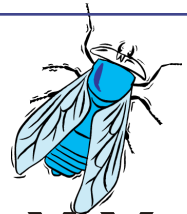
X^RX^R x  X^rY

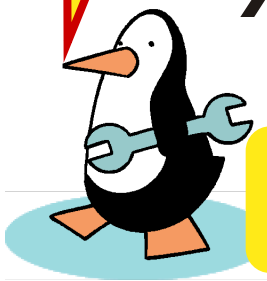


X^RX^r x  X^RY

	X^r	Y
X^R	 X^RX^r	 X^RY
X^R	 X^RX^r	 X^RY



	X^R	Y
X^R	 X^RX^R	 X^RY
X^r	 X^RX^r	 X^rY



100% red eyes

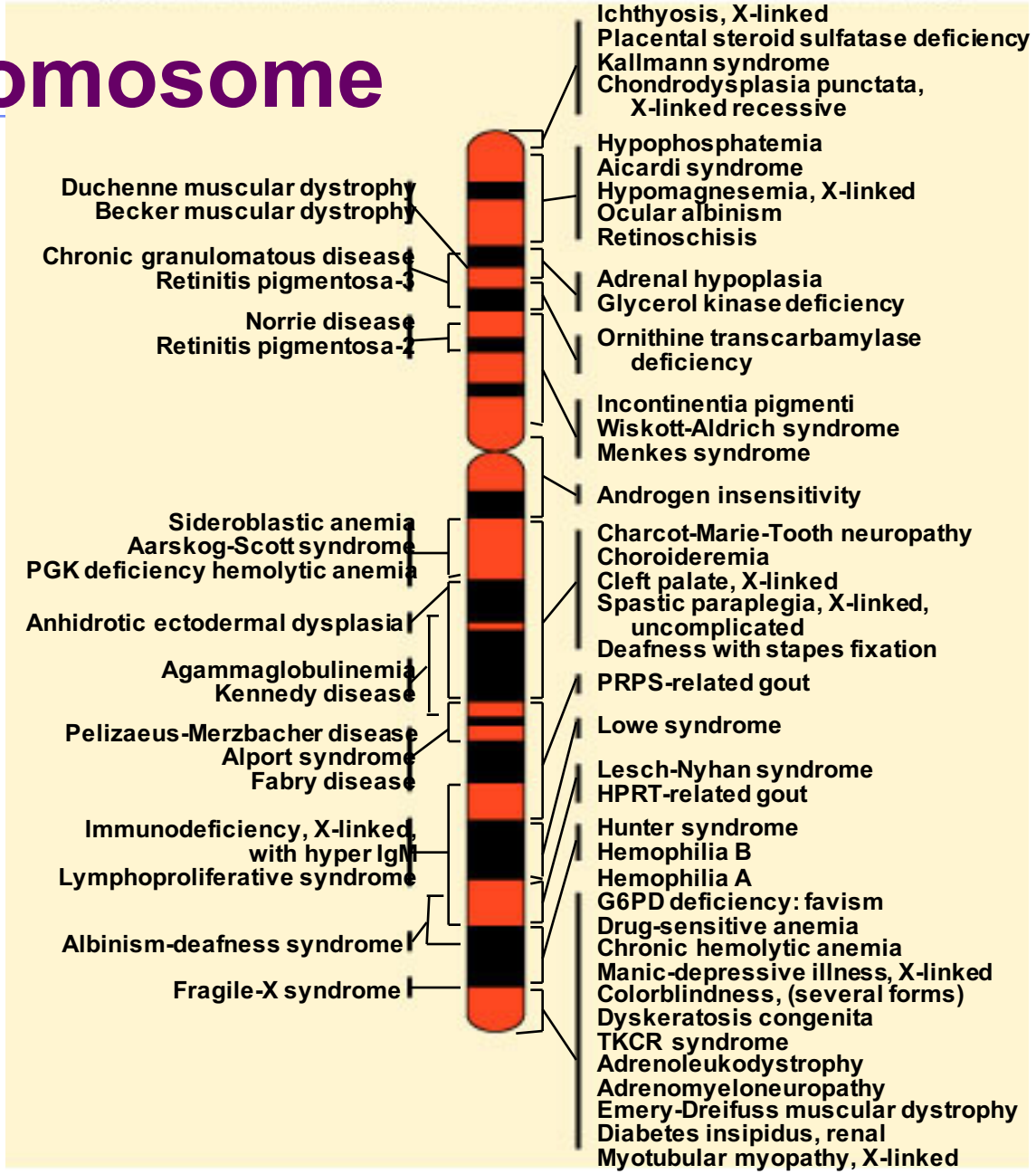
100% red females
50% red males; 50% white males

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

Human X chromosome

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



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)

Spitting (P2E)

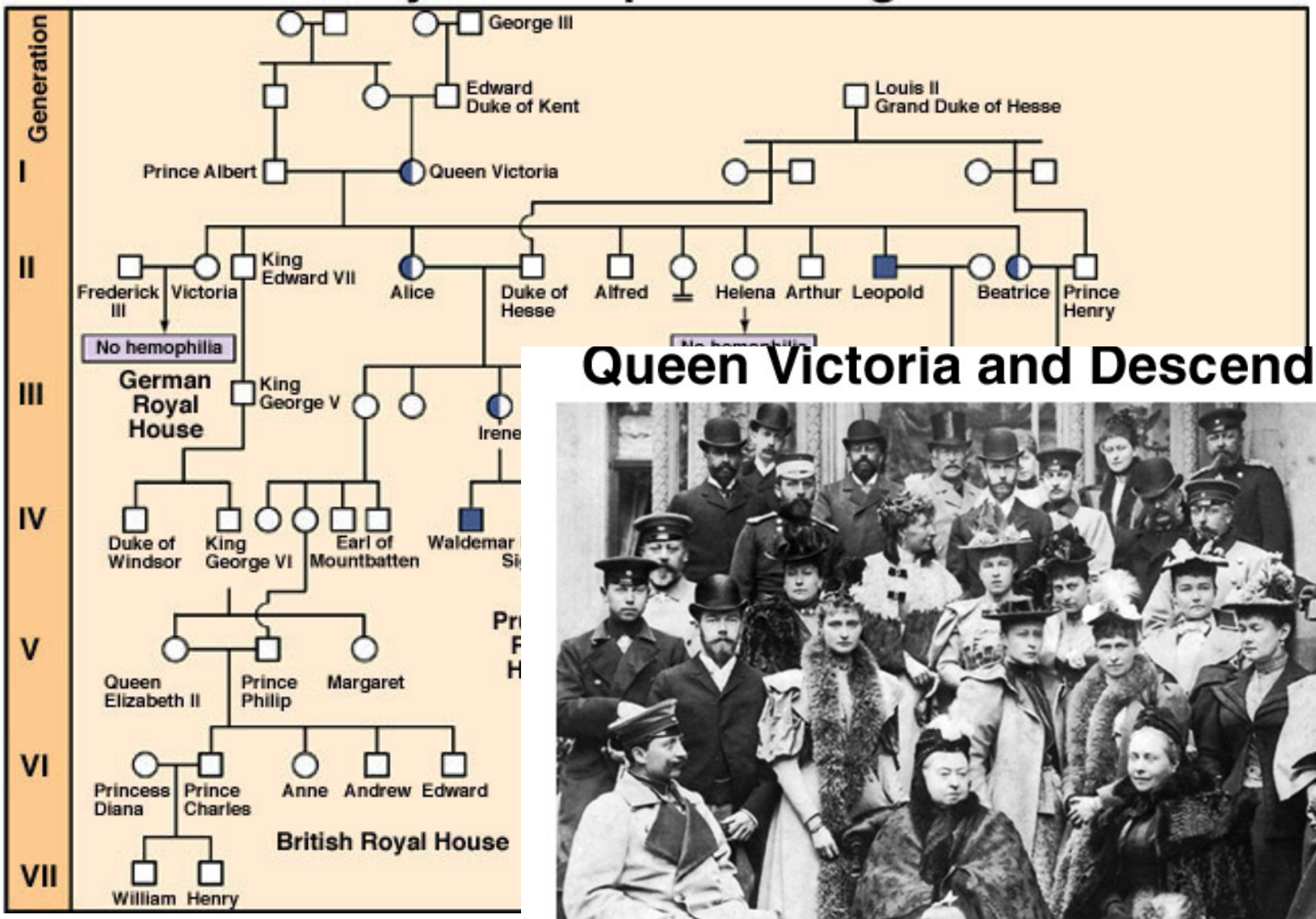
linked

Inability to express affection over phone (ME-2)

Selective hearing loss (HUH)

Total lack of recall for dates (OOPS)

Royal Hemophilia Pedigree

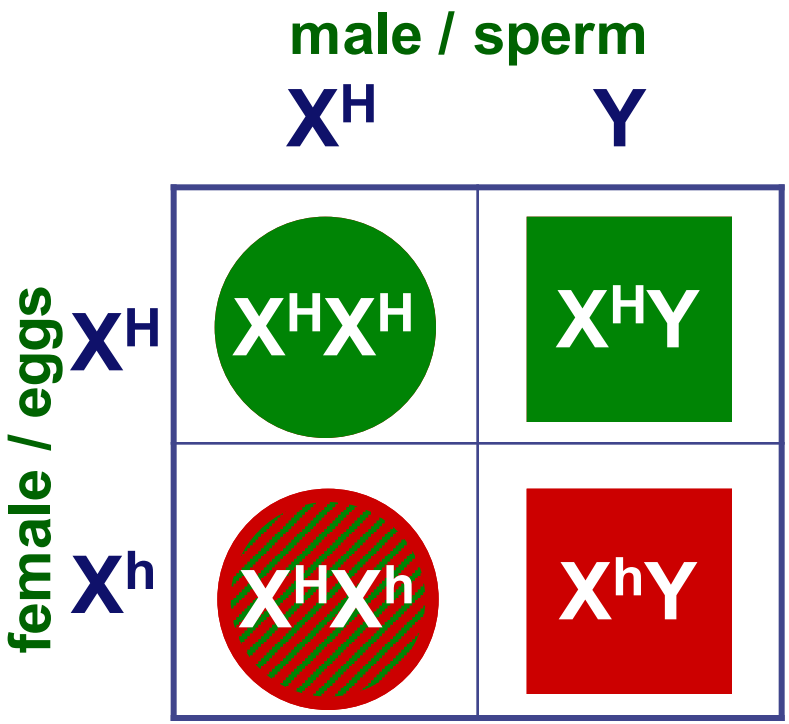


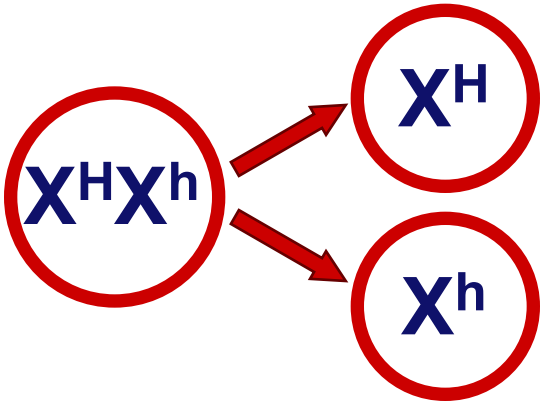
Queen Victoria and Descendants

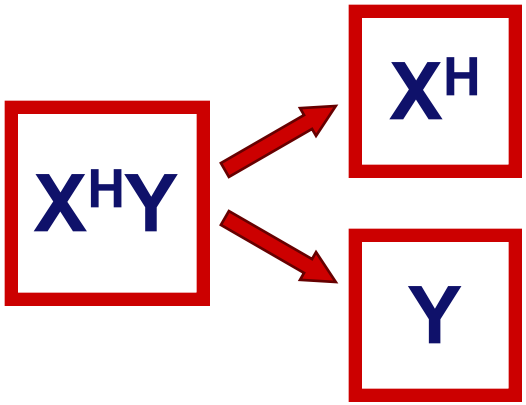
Hemophilia

sex-linked recessive

X^HX^h x X^HY



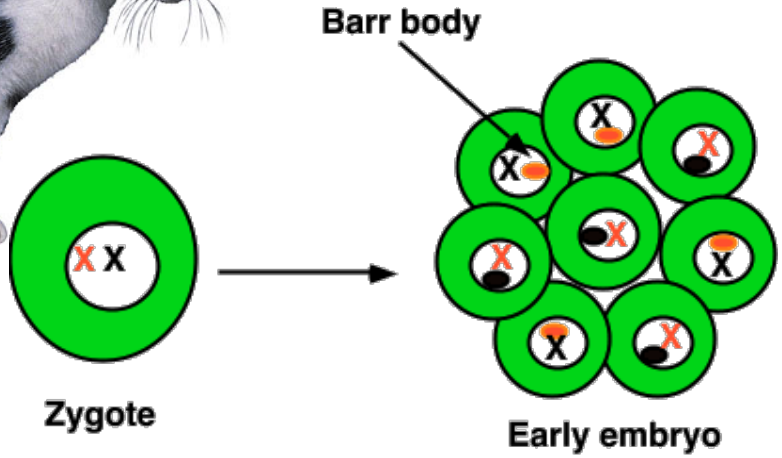


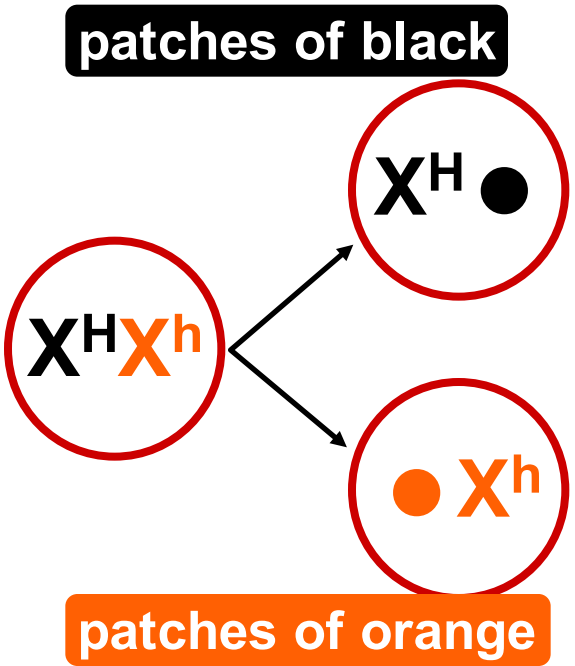


X-inactivation

- 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"

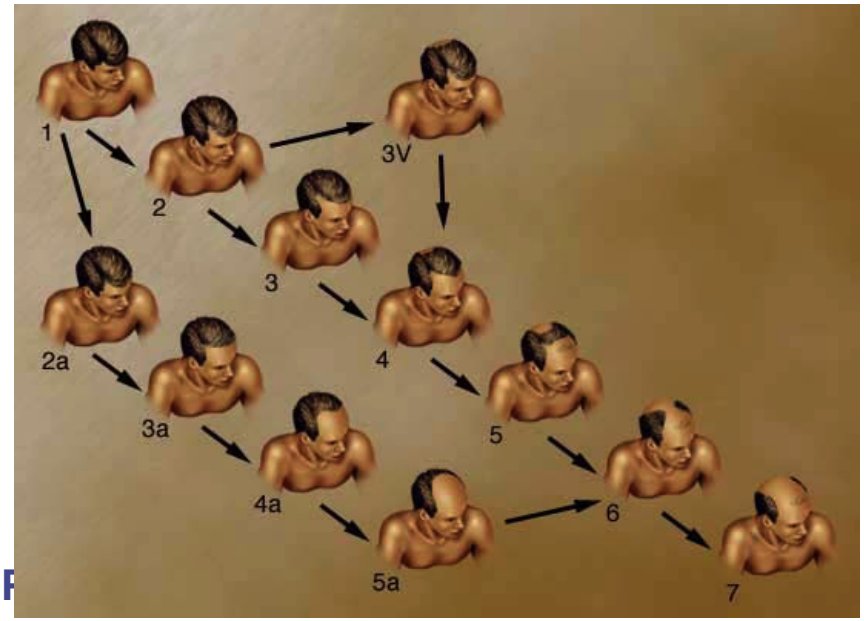
tricolor cats can only be female





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

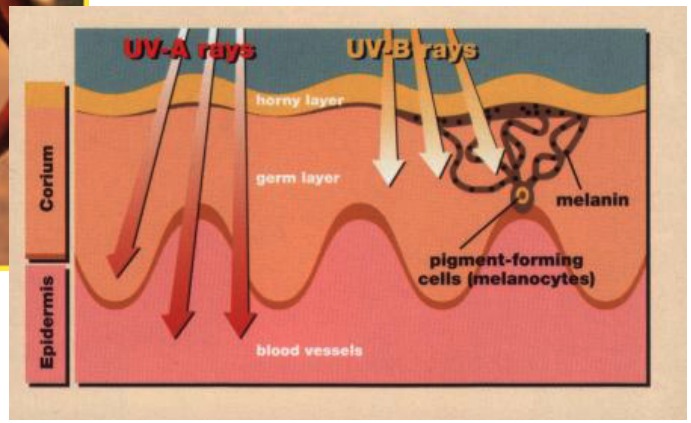
- Phenotype is controlled by both environment & genes

Human skin color is influenced by both genetics & environmental conditions

(a)

Coat color in arctic fox influenced by heat sensitive alleles

Color of Hydrangea flowers is influenced by soil pH



Any Questions?