Genetics

Dominance and Relationships

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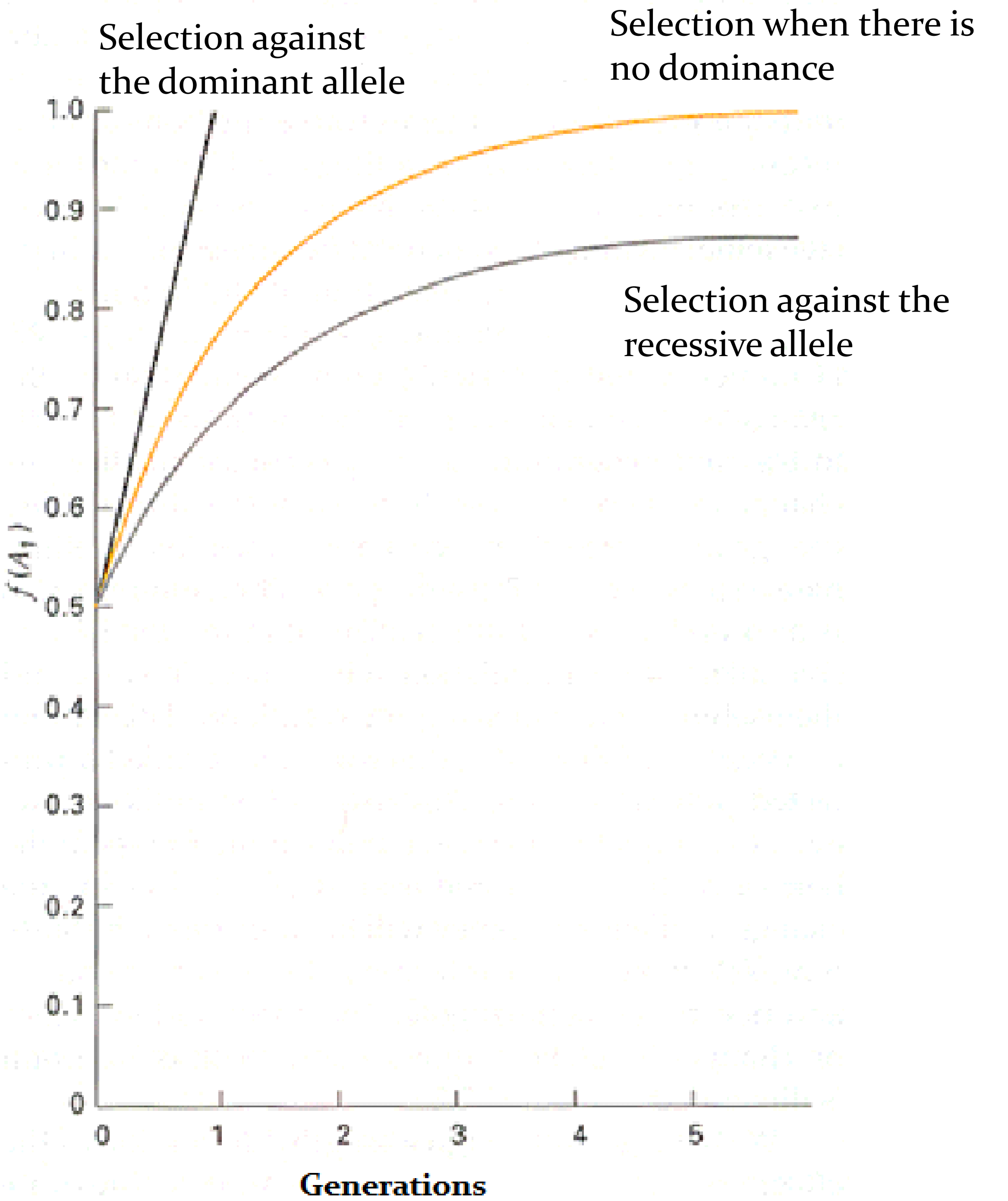
Selection Efficiency

- ❑Dominance does not always mean higher fitness (survival, reproduction).
- ❑Most of the dominant diseases have been eliminated.
- ❑When the recessive allele is less fit, or when there is artificial selection against it, the tail of the curve can be quite long. Why?
- ❑What kind of artificial selection people deal with?



Mating Methods

- Random mating
- Positive assortative mating
  - Based on genotypic similarities
  - Based on phenotypic similarities
- Negative assortative mating

Random mating

- Usually happens in plants
  - Bees-insects or wind carry pollen, may cross polinate to spread genes further afield
    - GM (genetically modified) pollen drift and insect pollination may create for nearby non-GM or organic crops.
  - No need to label products contaminated with less than 0.9% with GMOs in EU. Contamination could be from seed impurity, machine contamination when sowing or harvesting, cross fertilization and mixing during transport, storage and processing.

Random mating

- Classic farms have random mating
  - Bucks-rams are held within the herd, and mate with the ewes in heat (estrus)
- Random mating is the method in which the genetic variation is conserved the most.
  - Genetic diversification is generally seen as an adaptive strategy in unpredictable environments.

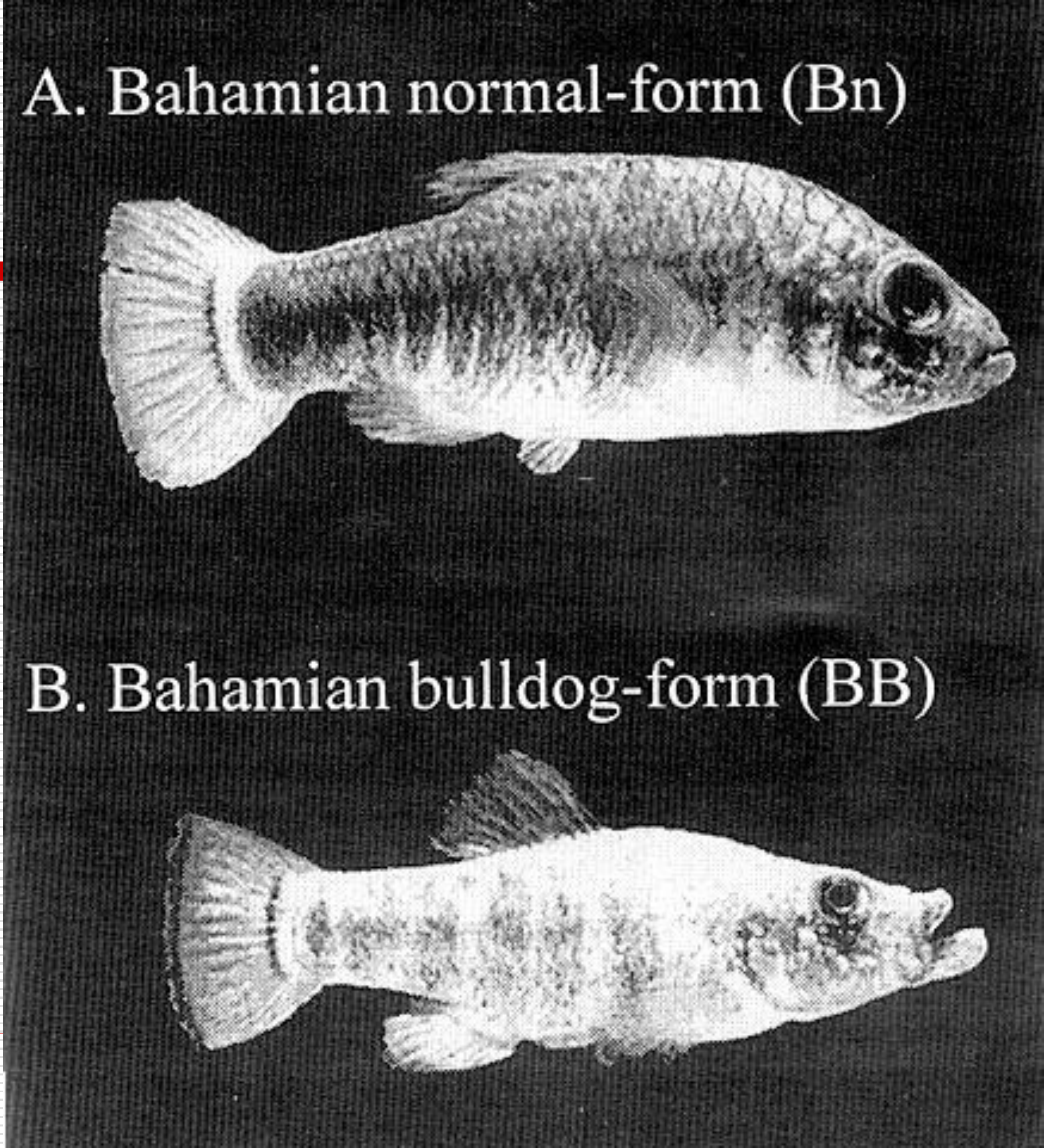
Positive assortative mating

- Mating of similar individuals
- Based on genotypic similarities
  - Inbreeding
- Based on phenotypic similarities
  - Part of the herd may be mated just to keep the phenotypic similarities.
  - Animals that show a breed's features well may be bred to take to shows and beauty pageants.

Nonrandom mating

- Positive assortative mating= Similar individuals mate more frequently than would be expected under a random mating pattern.
- Example: It is common for individuals of similar body size to mate with one another.
- This type of mating decreases the proportion of heterozygotes.

Tropic polymorphism causes strong assortative mating. Bn mate with their own, BB mate with their own

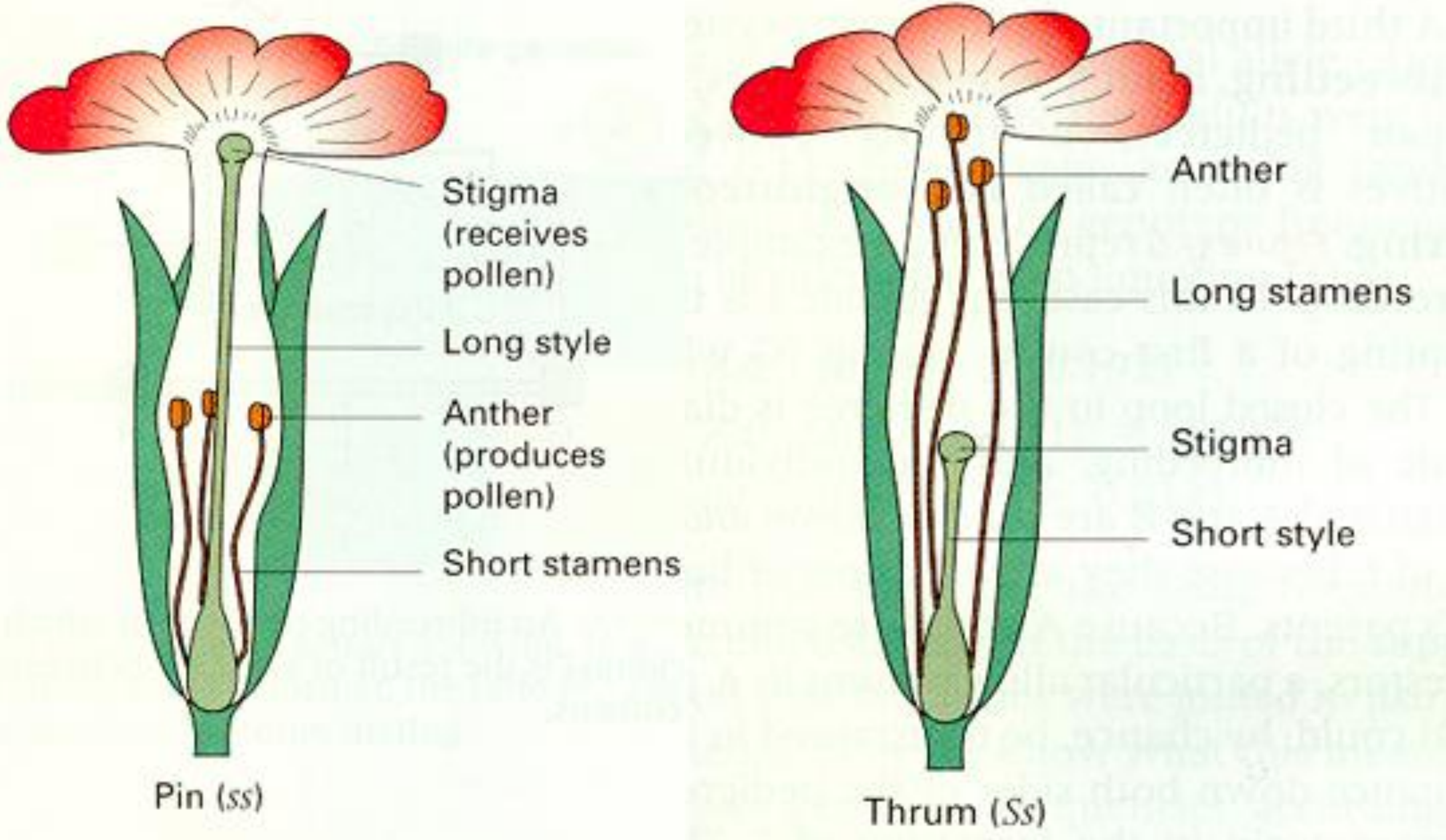


Nonrandom mating

- **Negative assortative mating** (disassortative mating) = individuals with diverse traits mate more frequently than would be expected under random mating
- Example: An experiment had subjects choose their preferred image with
  - an image modified to resemble the test subject
  - a non-resembling attractive face
  - a face more attractive than the resembling face, as determined by an outside group.

Nonrandom mating

- The study found that
  - male subjects preferred the female faces that resembled their own (assortative mating),
  - females did not prefer the male faces that looked like their own (disassortative mating).
- Negative assortative mating, or disassortative mating results in a greater number of heterozygotes.



Primula officalis flower Pin and Thrum forms. Anatomy of these flowers causes negative assortative mating: one sends pollen the other receives it.

Negative assortative mating: Based on genetic dissimilarities

- Genetically different individuals mate, those that are not relatives, or those that are different breeds.
- Purpose of these matings are to produce a phenotypically superior crossbred generation.
- Breeding values (additive) of these animals are not considered, instead gene combination values are used.

Negative assortative mating

- Recessive and lethal genes hide under heterozygosity
- They combine and come out as homozygosis increases.
  - Genetic variance may be low especially in low heritability traits.
  - Small genetic variance means genetically similar individuals.
  - Effects of inbreeding may be catastrophic for these traits. Why?

Negative assortative mating

- Genotypic variance of F_1 generation is less than the parental generation.
- Crossbred individuals are more resistant to environment compared to inbred individuals because they have various genes.
- Heterosis is the tendency for hybrid individuals to exceed their purebred parents in vigor, growth rate, reproduction, survivability etc.

Dominance, additive

- If there is additive gene action:
  - A=1, AA=1+1=2, Aa=1+0.5=1.5
  - a=0.5, aa=0.5+0.5=1
- If complete dominance:
  - AA=2
  - Aa=2
  - aa=1

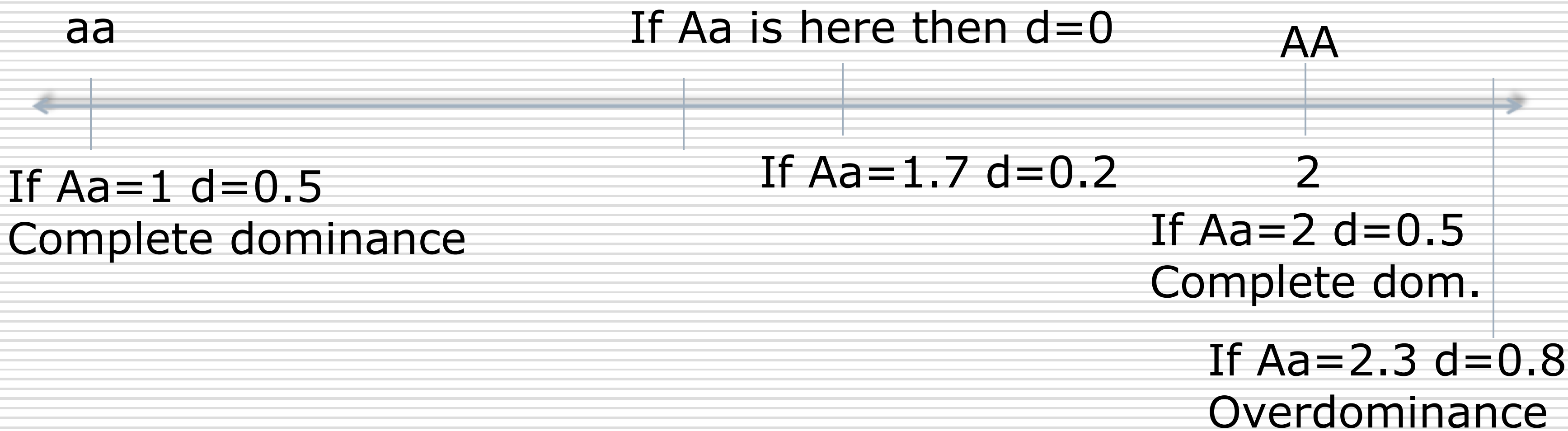
Dominance, additive

- If incomplete dominance:
  - AA=2
  - Aa=1.7, or 1.8 etc.
  - aa=1
- If there is overdominance:
  - AA=2
  - Aa=2.1 or 2.5 etc.
  - aa=1

Dominance, additive

- If complete dominance for a:
  - AA=2
  - Aa=1
  - aa=1

Dominance, additive



Negative assortative mating, Two theories

- Two theories for the benefit of heterozygosity exist
  - Complete dominance
  - Overdominance

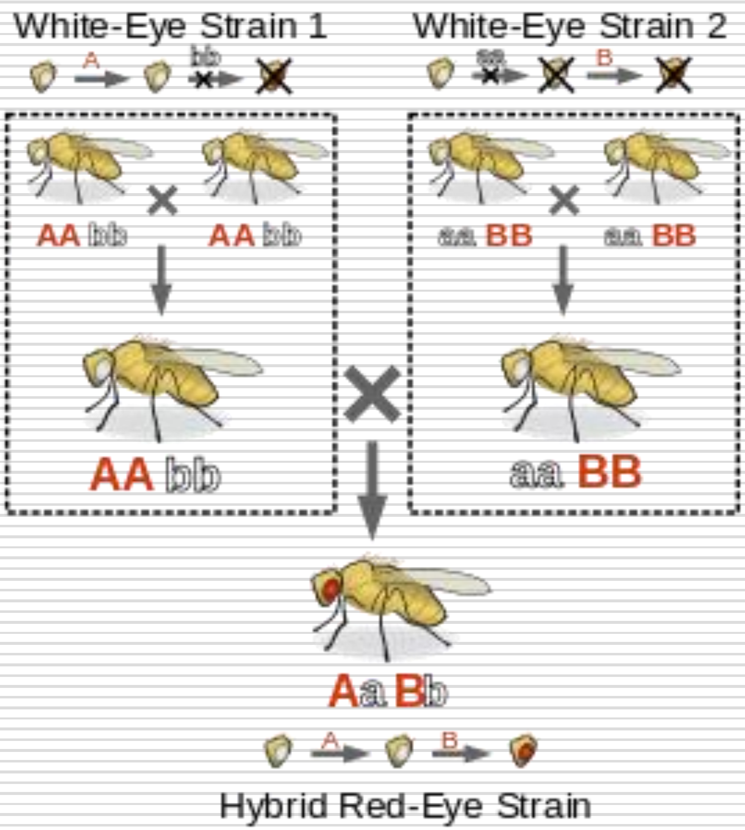
Two theories, Dominance versus Overdominance

- Two competing genetic hypotheses, not necessarily mutually exclusive, have been developed to explain hybrid vigor.
- More recently, an epigenetic component of hybrid vigor has also been established.
  - Ni Z, Kim ED, Ha M et al. (January 2009). "Altered circadian rhythms regulate growth vigour in hybrids and allopolyploids". Nature 457 (7227): 327–31.
  - Baranwal VK, Mikkilineni V, Zehr UB, Tyagi AK, Kapoor S (November 2012). "Heterosis: emerging ideas about hybrid vigour". J. Exp. Bot. 63 (18): 6309–14.

Dominance

- The genetic **dominance hypothesis** attributes the superiority of hybrids to masking the expression of undesirable (deleterious) recessive alleles from one parent by dominant (usually wild-type) alleles from the other.
- It attributes the poor performance of inbred strains to the expression of homozygous deleterious recessive alleles.

Complete Dominance: complementation



- If mutations are in different genes, complementation occurs.
- A complementation test example. Two strains of flies are white eyed because of two different autosomal recessive mutations which interrupt different steps in a single pigment-producing metabolic pathway.
- Flies from Strain 1 have complementary mutations to flies from Strain 2 because when they are crossed the offspring are able to complete the full metabolic pathway and thus have red eyes.
- Effects of hybrid vigor is seen in polygenic traits.

Overdominance

- The genetic overdominance hypothesis states that some combinations of alleles (by crossing two inbred strains) are advantageous when paired in a heterozygous individual.
- This hypothesis is used to explain the persistence of some alleles (such as the Sickle cell trait allele) that are harmful in homozygotes. PKU and Warfarin are two other examples.

Overdominance

- Under normal circumstances, such harmful alleles would be removed from a population through the process of natural selection.
- Like the dominance hypothesis, it attributes the poor performance of inbred strains to expression of such harmful recessive alleles.
- In any case, outcross matings provide the benefit of masking deleterious recessive alleles in progeny.
- This benefit has been proposed to be a major factor in the existence and maintenance of sexual reproduction among eukaryotes. It introduces shuffling of genes for increased genetic variance.

Epigenetic heterosis

- An epigenetic contribution to heterosis has been established in plants, and it has also been reported in animals.
- MicroRNAs (miRNAs), discovered in 1993 in C. Elegans, are a class of non-coding small RNAs which repress the translation of messenger RNAs (mRNAs) or cause degradation of mRNAs (RNA silencing).
- In hybrid plants, most miRNAs have non-additive expression (it might be higher or lower than the levels in the parents).
- This suggests that these small RNAs are involved in the growth, vigor and adaptation of hybrids.
- Produced from the introns, miRNAs turn off genes, helping different proteins made in different cells. The cells have the same genes, but they are different.

Epigenetic heterosis

- miRNAs sometimes cause histone modification and DNA methylation of promoter sites, which affects the expression of target genes (gene regulation).
- It was also shown that hybrid vigor in a hybrid of two Arabidopsis species was due to epigenetic control in the upstream regions of two genes, which caused major downstream alteration in chlorophyl and starch accumulation.
- The mechanism involves methylation of specific amino acids in histone H3, a protein closely associated with DNA, which can either activate or repress associated genes.

Introns

- Transcription, the conversion of DNA to RNA, is one of the most fundamental processes in cell biology.
- However, only about 3% of our total DNA encodes genes to be transcribed.
- RNA polymerase II, the enzyme that transcribes DNA to RNA, relies on a large set of proteins known as transcription factors to recognize the coding sequences and to transcribe the correct genes, in the correct cell type, at the correct time.

Complete dominance

- AA=2
- Aa=2
- aa=1
- 4 loci, recessive genotypes contribute 1 unit to phenotype, dominants 2

AA bb CC dd x aa BB cc DD

2 +1+ 2 +1=6 1 + 2 + 1 + 2=6

F_1: AaBbCcDd

2+2+2+2=8

OverDominance

- 4 loci, recessive genotypes contribute 1 unit to phenotype,
- heterozygous genotypes 2 unit,
- homozygous dominants 1.5 unit.

aa bb CC DD x AA BB cc dd

1+1+1.5+1.5=5 1.5+1.5+ 1 + 1=5

F_1: AaBbCcDd

2+2+2+2=8

Inbreeding

Positive Assortative Mating

Inbreeding

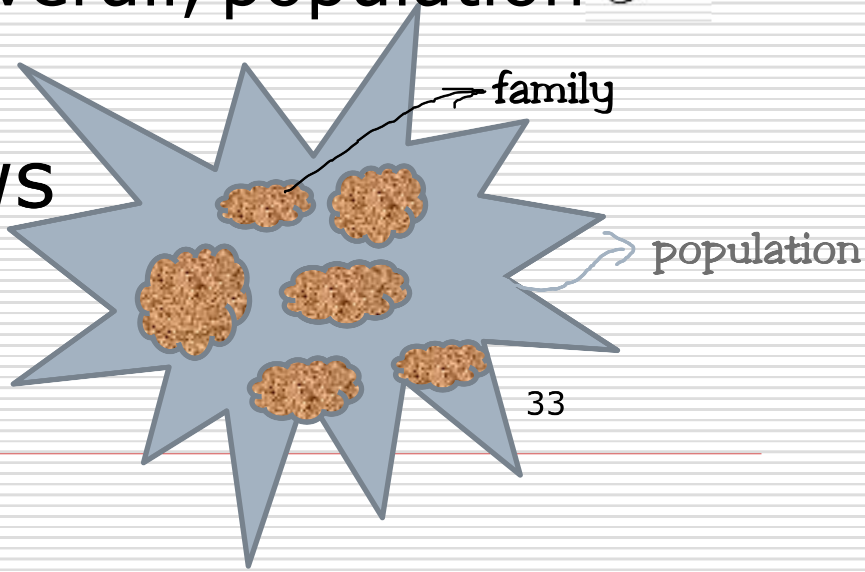
- **Inbreeding** is positive assortative mating because individuals mate with relatives and these relatives are genetically similar to them.
- Inbreeding is measured using the coefficient F.
- F is the amount of decrease in heterozygosity. This decrease occurs in the heterozygosity expected under HW equilibrium (2pq).

Important Point:

- Inbreeding can decrease heterozygosity but does not decrease genetic variation by itself.
- Selection is added to inbreeding if σ^2 is to be decreased.
- Select and breed some family groups, and send the other families away

Inbreeding and Selection

- σ^2 decreases because family members resemble each other.
- Families are like subpopulations:
  - With inbreeding only, within group σ^2 decreases but the overall, population σ^2 stays the same.
- Lions and three cows



Coefficient of inbreeding & Coefficient of relationship

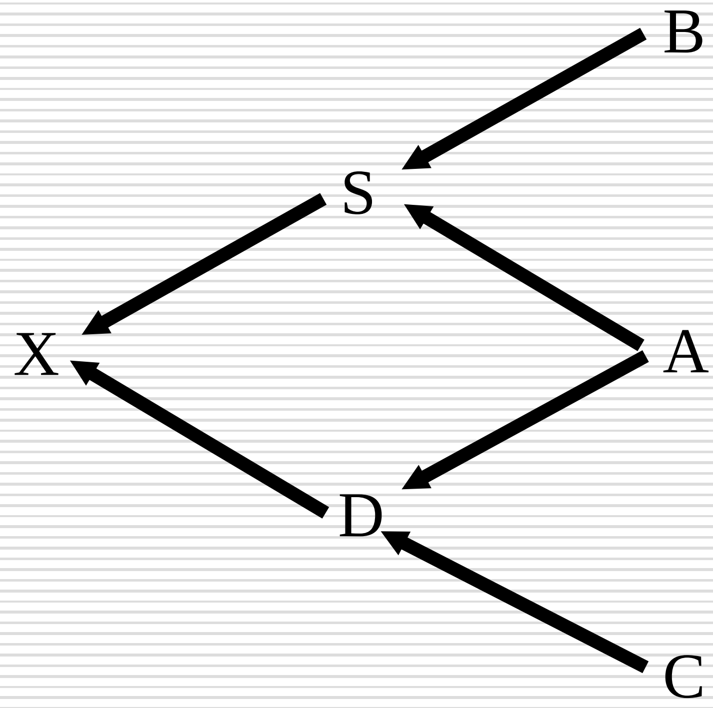
- We look like each other, Why?
- We have common ancestors ☺
- Because of their common ancestors, two animals or plants carry common genes: *identical by descent*
- As relatives are closer, they carry more common genes. Brothers carry more idb genes compared to cousins.

Coefficient of inbreeding & Coefficient of relationship

- Each individual inherit half of their genes from their mother, and the other half (1/2) from their father.
- This is called ***Coefficient of Relationship***= Ratio of the genes identical by descent in two individuals.

Arrow Diagram

Each arrow is ½ because ½ genes are transmitted from each parent



S and D are half sibs=half siblings

Coefficient of relationship in some relatives. More common genes in closer relatives

Identical twins, clones	1
Full sibs	½ (0.50)
Parent-offspring	½ (0.50)
Half sibs	¼ (0.25)
Grandparent-grandchild	¼ (0.25)
Uncle/aunt	¼ (0.25)
Cousins	1/8 (0.125)
Half cousins (from half sibs)	1/16 (0.06)

Coefficient of inbreeding & Coefficient of relationship

- The inbreeding coefficient is defined as the probability of homozygosity in a locus due to common ancestors.
- Thus the inbreeding coefficient for an animal (F) is equal to half of the relationship coefficient between the parents.
- The relationship coefficient (R) is between two individuals.

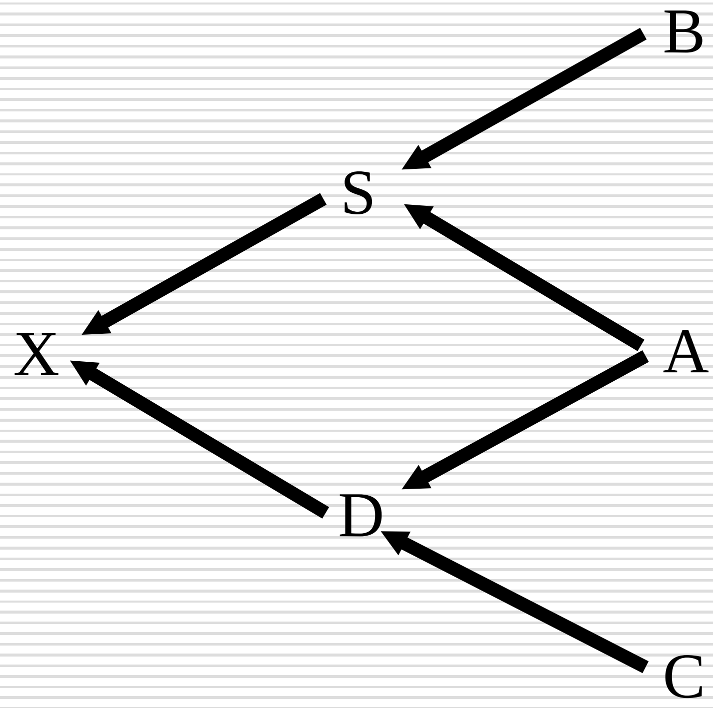
Inbreeding depression

- Depression?
- Inbreeding depression is the reduced biological fitness in a given population as a result of inbreeding - that is breeding of related individuals.
- Decrease in biological fitness lead to changes in reproduction performance and ability to survive.

Inbreeding depression

- Inbreeding depression in natural population is often the result of a population bottleneck.
- The higher the genetic variation within a breeding population, the less likely it is to suffer from inbreeding depression.
- Traits with low heritability (reproduction and survival) suffer worse from depression

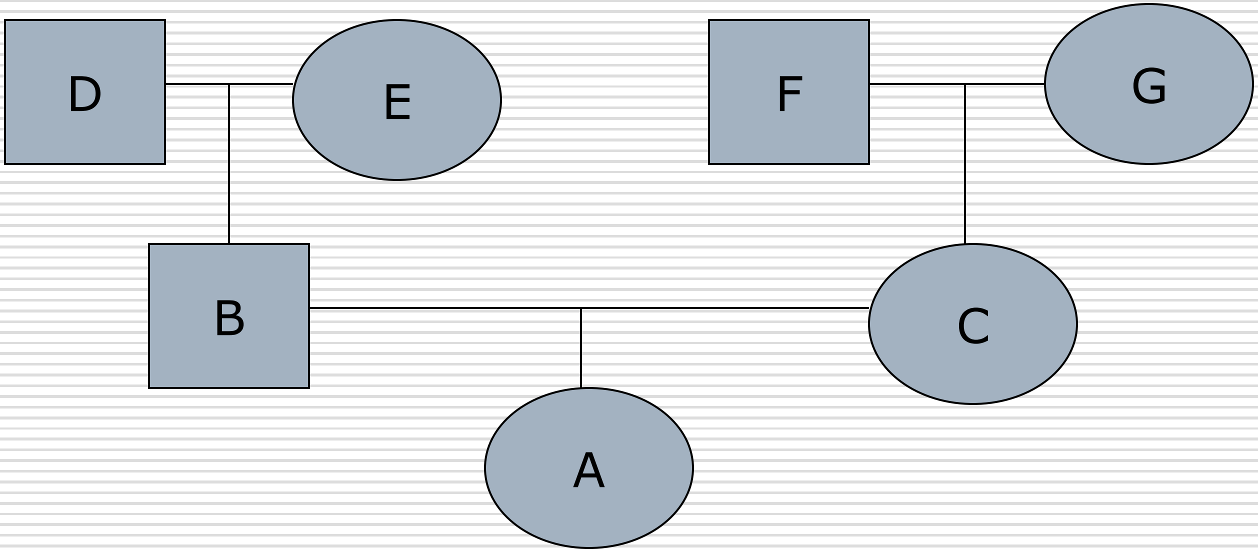
Arrow Diagram



R_{SD} = ¼ (half sibs). F_X = (¼)/2 =1/8

Genetic positive assortative mating: Inbreeding

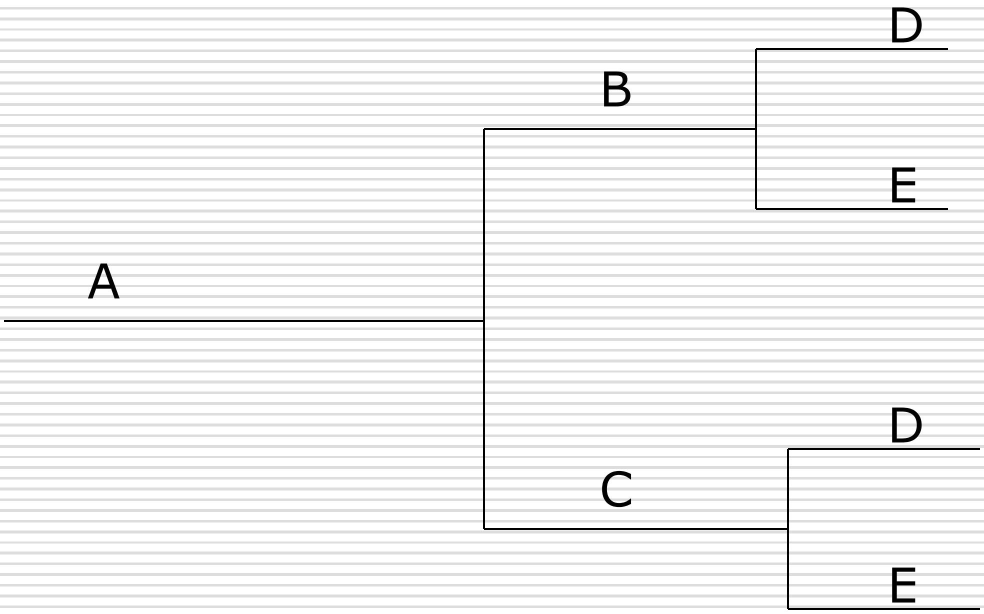
- Inbreeding is mating individuals that have stronger relationships thans the other individuals in the population.



B are C not relatives, inbreeding (F) is zero

Coefficient of inbreeding & Coefficient of relationship

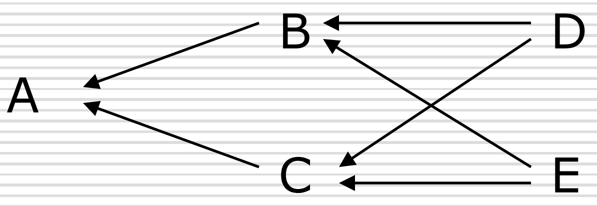
Fathers are represented with letters at the top and moms are represented with the letters at the bottom.



Coefficient of inbreeding & Coefficient of relationship

Coefficient of relationship is the percentage of idb genes carried by two individuals due to common ancestors.

Coefficient of relationship can be calculated by following paths over common ancestors.



$$R = \sum_{i=1}^{n} \left(\frac{1}{2}\right)^{S}$$

n= # of paths over common ancestors

s=# of arrows from the individual to common ancestor and then to the other individual

Inbreeding Coefficient

- Inbreeding coefficient is the probability that two alleles in a locus is identical by descent.
- These two genes (alleles) are copies of a gene replicated from a common ancestor.

Inbreeding Coefficient

- Half of the coefficient of relationship is the inbreeding coefficient of the offspring of these two individuals.
  - The common ancestor must have a zero inbreeding coefficient

$$F_x = \frac{1}{2} R_{SD} = \sum_{i=1}^{n} \left(\frac{1}{2} \right)^{p_1 + p_2 + 1}$$

1 is added to add a ½ for F

  - S dad, D mom, p_1 #of arrows from one parent to the common ancestor, p_2 #of arrows from the other parent to the same common ancestor, we add it all up.

Inbreeding Coefficient

- If the common ancestor is inbred, the formula has an addition:

$$F_x = \sum_{i=1}^{n} \left[\left(\frac{1}{2} \right)^{p_1 + p_2 + 1} \left(1 + F_A \right) \right]$$

Coefficient of inbreeding & Coefficient of relationship

- Why use inbreeding since it is so bad?
- May want to mate a good male with more females,
  - Even a superior individual may be cloned
- Many breeds are developed using inbreeding
- Assortative mating may be required for sympatric speciation, meaning the evolution of a new species without geographic isolation.

Inbreeding or not inbreeding? 1. Positive effects

- Inbreeding may fix some gene combinations and make sure it is transmitted to the next generations.
- Purebreds may be wanted for hybrids
- Lines within purebreds may be desired for hybrids
- Inbred strains (lines) may be desired for scientific studies
  - the usual procedure is mating of brother-sister pairs for a minimum of 20 generations

Inbreeding or not inbreeding?
2. Negative effects

- Inbreeding causes genes with deleterious effects to come out and decreases general vigor, causing inbreeding depression.
- Low h^2 traits such as reproduction and survivability are affected.
- Inbreeding is usually avoided due to its bad effects

Hybrids

- Wild mice warfarin resistance
  - Vitamin K coagulates blood
  - Warfarin prevents blood coagulation (clotting) and it is used as a rat/rodent poison
- Two alleles, **K** and **k**
- **kk** mice get sick due to Vitamin K defficiency
- **KK** mice die if given Warfarin
- **Kk** mice are resistant to Warfarin and they don’t have Vitamin K deficiency

Heterosis=Reverse inbreeding

- Heterosis and its applications are why chicken, corn etc. are cheaper.
  - White meat was more expensive/guest food when I was a kid.
- Hybrid vigor is an offspring performing better than the average of its parents. It is the improved or increased function of any biological quality in a hybrid offspring.
- An offspring exhibits heterosis if its traits are enhanced as a result of mixing the genetic contributions of its parents.
- Hybrid animals usually have better reproductive capabilities compared to purebreds. Malaria- sickle cell anemia

Heterosis 2

- Why hybrid animals-for example chicken is not used for producing chicks, but the farmers purchase a new crop of chicks each time??
- Why progeny from hybrid parents do not perform as well as its hybrid parents?
- How can these genetic companies sell animals/seeds continuously?

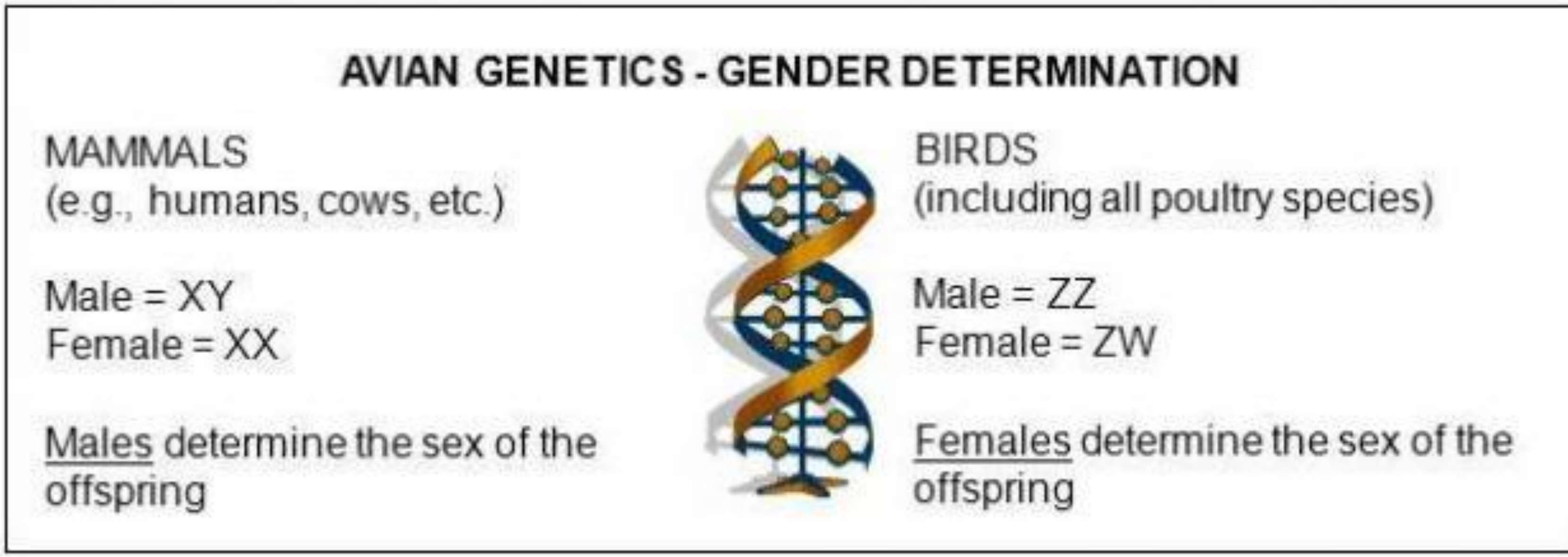
Gender in Poultry

- The male reproductive organs are located on the outside of the body and are relatively easy to see, even in newborns.
- In male birds, the reproductive organs are inside the body cavity.
  - This makes sexing newly hatched chicks difficult.

Gender in Poultry

- Cloaca can be squeezed gently, allowing the chicken sexer to see if the chick has a small "bump", which would indicate that the chick is a male.
  - This is called venting, and requires experience.
- Cloaca is the only opening for the intestinal, reproductive, and urinary tracts of all amphibians, birds and reptiles possess this orifice, from which they excrete both urine and feces.
  - Chicken/pigeon fertilizer is more valuable.
- Placental mammals possess two or three separate orifices for evacuation.

ZW sex determination



ZW sex determination

- In the ZW system, the ovum determines the sex of the offspring, in contrast to the XY sex-determination system and the X0 sex-determination system, wherein the sperm determines the sex.
- The letters Z and W are used to distinguish this system from the XY system.
- Males are the homogametic sex (ZZ), while females are the heterogametic sex (ZW).
- The Z chromosome is larger and has more genes, just like the X chromosome in the XY system.

ZW sex determination

- It is unknown whether the presence of the W chromosome induces female features or the duplication of the Z chromosome induces male ones;
- unlike mammals, no birds with a double W chromosome (ZWW) or a single Z (Z0) have been discovered.
- It appears possible that either condition could cause embryonic death, or that both chromosomes could be responsible for sex selection.
  - Smith CA, Roeszler KN, Hudson QJ, Sinclair AH (2007). "Avian sex determination: what, when and where?". Cytogenet. Genome Res. 117 (1–4): 165–73.

Gender in Poultry

- The Barred Plymouth Rock breed carries a gene for barring (B) that is carried on the Z chromosome.
- This gene produces a white bar on normally a black feather.
- The gene has incomplete dominance over the non-barring gene (b).
- In adults, the male, with two barring genes (BB), has feathers with broader white bars than those of the female, who has only one of the barring genes (B_).
- As a result, females are overall lighter in color.

Gender in Poultry

- Male offspring get a Z chromosome from each parent
- Females get a Z from their father and a W from their mother
- Z chromosomes never pass from mother to daughter
- W chromosomes always pass from mother to daughter

B = Barred b = non-barred

FEMALE

MALE	Z^B	W
Z^B	Z^BZ^B	Z^BW
Z^B	Z^BZ^B	Z^BW

Z^BZ^B = Barred male with broad white bars
Z^BW = Barred female with more narrow white bars

Silver/Gold for sexing

- Another characteristic that has been used in some commercial strains is the silver (S) and gold (s) color alleles. Gold males are mated to silver females.
- Z^sZ^s x Z^SW ----→ Z^sZ^S and Z^sW
- The resulting males will be silver, females will be gold.
- The silver and gold genes have been used in both the egg and meat chicken (broiler) industries.
- Some of the strains of brown-shelled egg layers have the silver/gold sexing characteristics.
- The gold/silver and barred/non-barred genes have been combined and used in some commercial brown-shell egg layers.

Silver/Gold for sexing

S = silver   s = gold

FEMALE

MALE	Z^S	W
Z^s	Z^SZ^s	Z^sW
Z^s	Z^SZ^s	Z^sW

Z^SZ^s = Silver male
Z^sW = Gold female

B = Barred   b = non-barred
S = silver   s = gold

FEMALE
Barred Plymouth Rock (silver, barred)

MALE *Rhode Island Red (gold, non-barred)*	Z^{SB}	W
Z^{sb}	$Z^{SB}Z^{sb}$	$Z^{sb}W$
Z^{sb}	$Z^{SB}Z^{sb}$	$Z^{sb}W$

$Z^{SB}Z^{sb}$ = Black and white barred male
$Z^{sb}W$ = Black-red, non-barred female

Gender in Poultry

Gender in Poultry