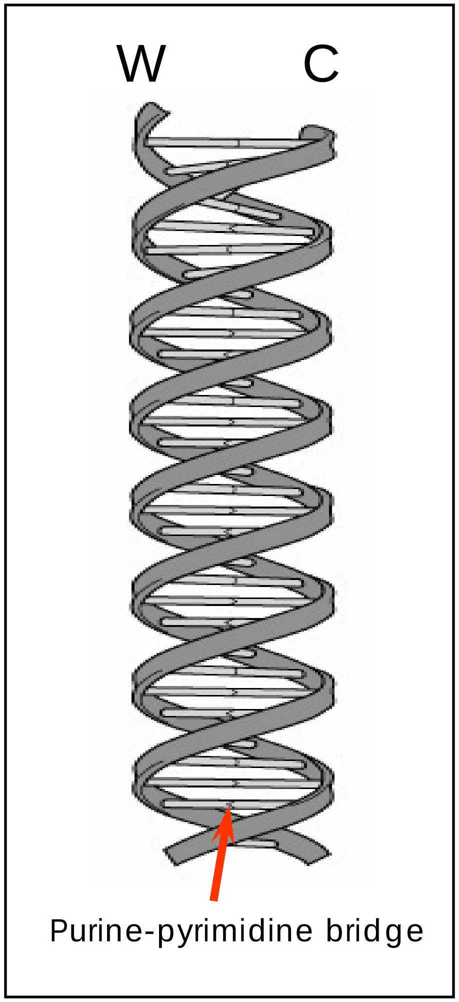
Lecture 1:
Biological Genetics and Evolution

Suggested Reading

- James F. Crow, *Genetic Notes*: *An Introduction to Genetics*, 8th Edition

Structure of DNA (Deoxyribonucleic Acids)

- Discovered by James Watson and Francis Crick in 1953
- DNA has double-helical structure
- The longitudinal strands made of phosphate and 5-carbon sugar called deoxyribose
- The linkages between two strands are purine-pyrimidine bridges
- Helix makes 360° turn every 10 steps
- W&C for Watson and Crick, who discovered this structure



The Purine-Pyrimadine Bridge

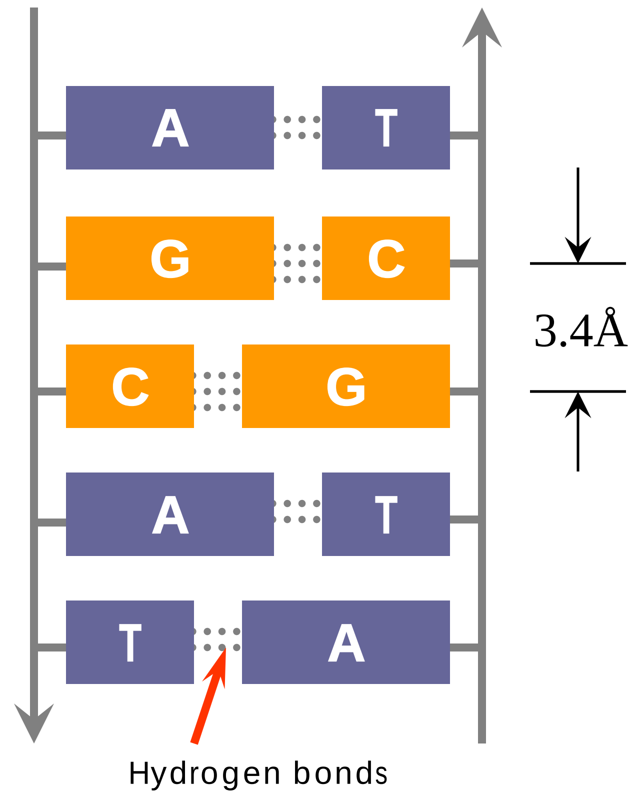
- Types of Purines
  - Adenine (A) (paired with T)
  - Guanine (G) (paired with C)
- Types of Pyrimidine
  - Thymine (T) (paired with A)
  - Cytosine (C) (paired with G)

The Purine-Pyrimidine Bridge

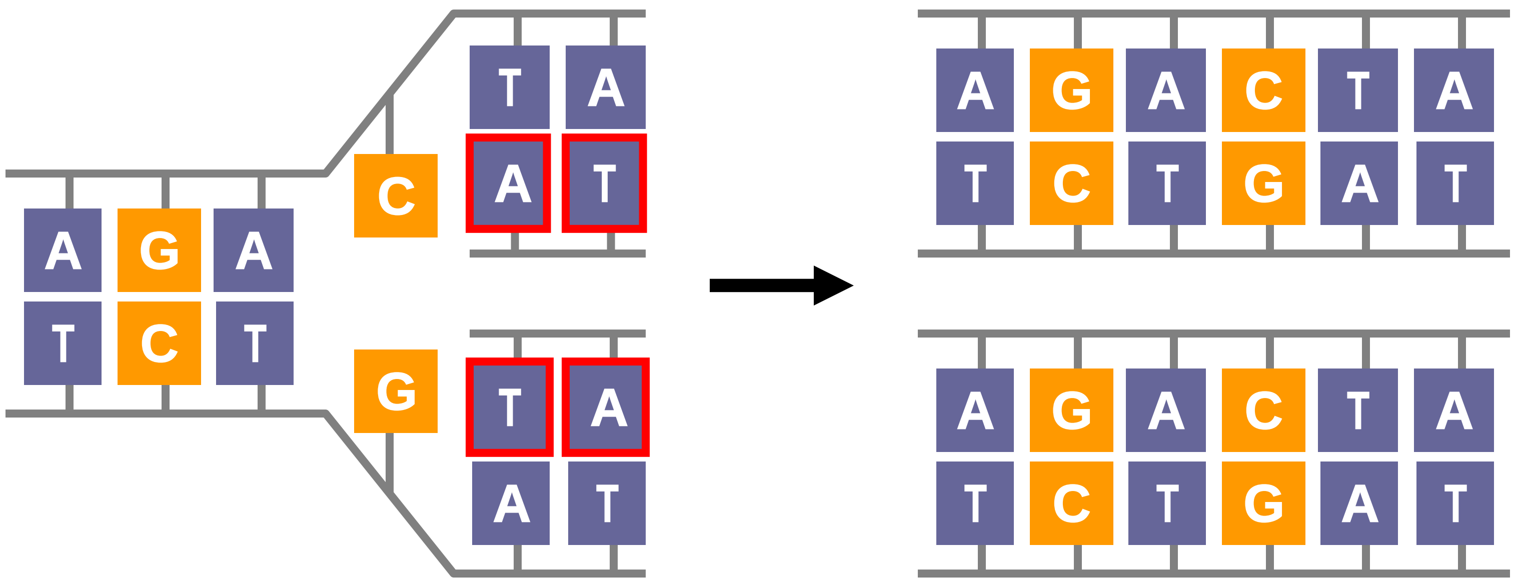
- Result – 4 Letter Alphabet
  - AT
  - TA
  - GC
  - CG

  Note: AT isn't TA

- Sequence carries information
  - 1000 steps can carry 4^{1000} different messages



DNA Replication



DNA Amounts in Humans

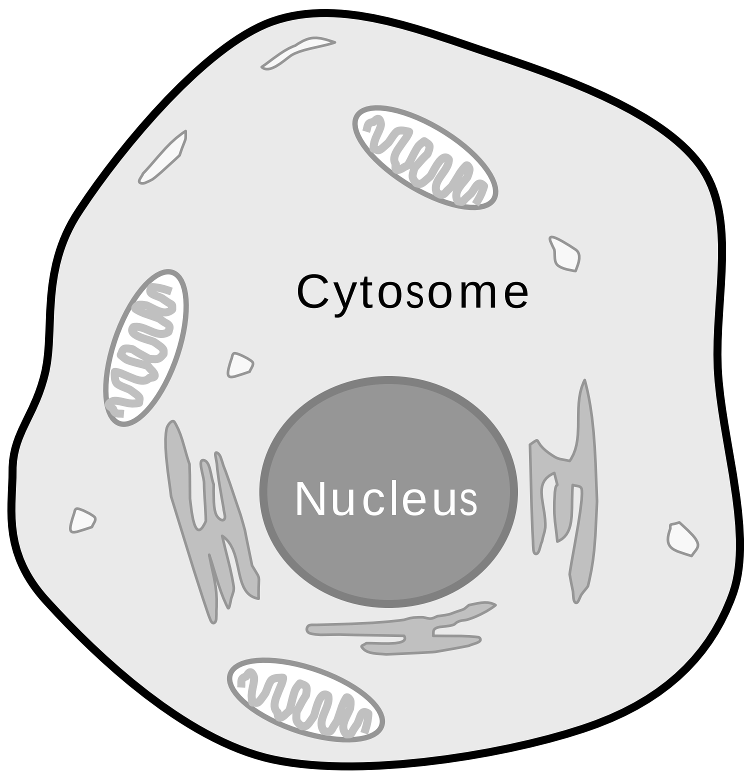
- Humans have 3.4×10^6 base pairs (haploid)
- Total length in diploid cells is 2 m (average chromosome length is about 4 cm)
- Arrangement within nucleus is a mess
- How this sorts itself out not understood

DNA in Different Species

E. Coli:	1	(per unit)
Yeast:	4	
Drosophilae:	20	
Silk Moth:	60	
Carp:	500	
Human:	1000	
Newt:	10,000	
Lily:	50,000	

Cells and Cell Division

- Cell Structure:
  - Nucleus
  - Cytosome (Cytoplasm)



- Cell Size:
  - Ostrich egg is single cell
  - E-coli is 2 μ by 0.5 μ
  - Whale and Giraffe nerve cells are several feet long
  - Humans have 10^{14} cells

Chromosomes in Cell Nucleus

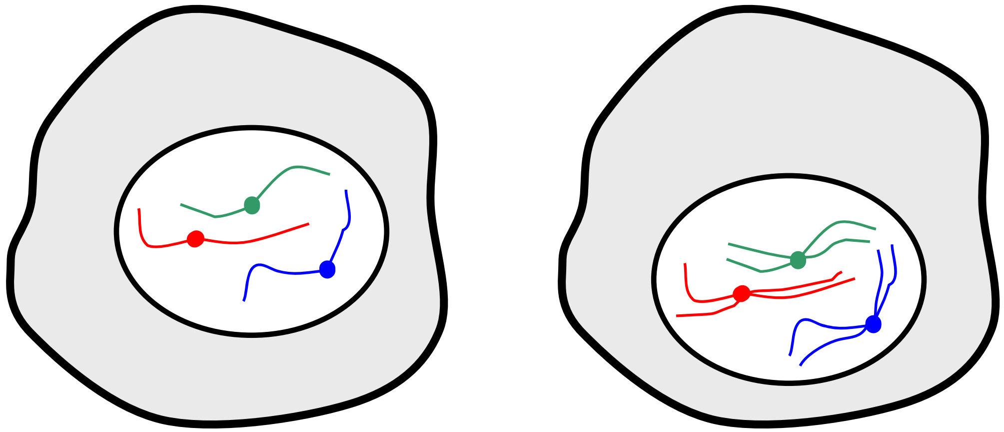
- Humans are diploid
- Wasps, bees, and ants are haploid
- Potatoes are tetraploid
- Wheat is hexaploid
- Strawberries are octaploid

Mitosis (Nuclear Division)

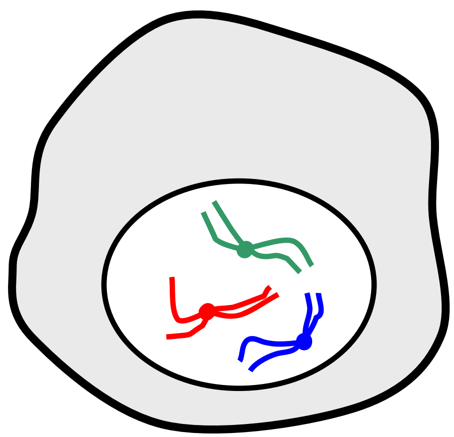
- Cytoplasm divides more or less equally between cells
- Chromosomes undergo precise process that insures that an equal number of chromosomes is distributed to each of the new cell

Mitosis

- Interphase:

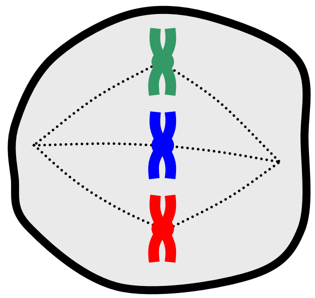


- Prophase

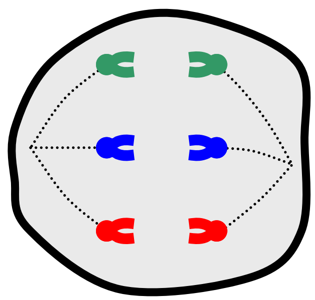


Mitosis

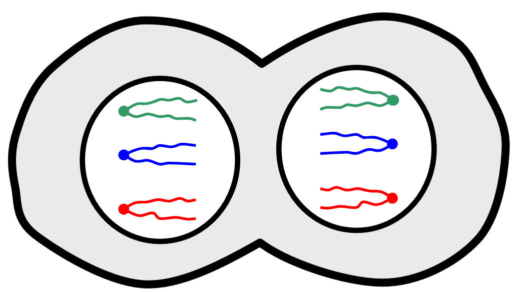
- Metaphase



- Anaphase

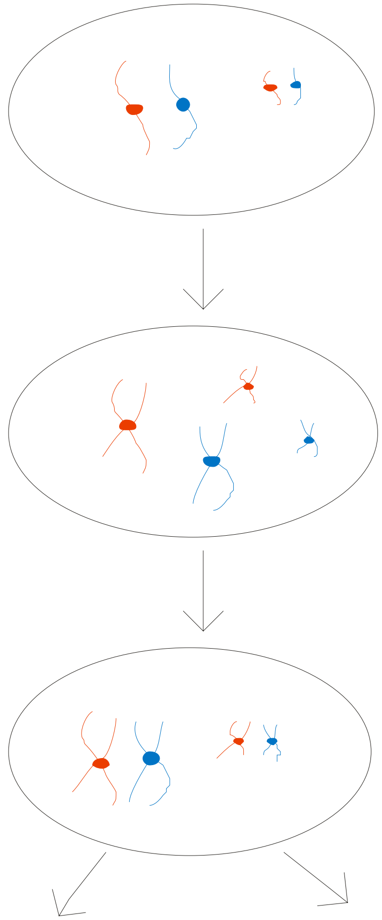


- Telophase



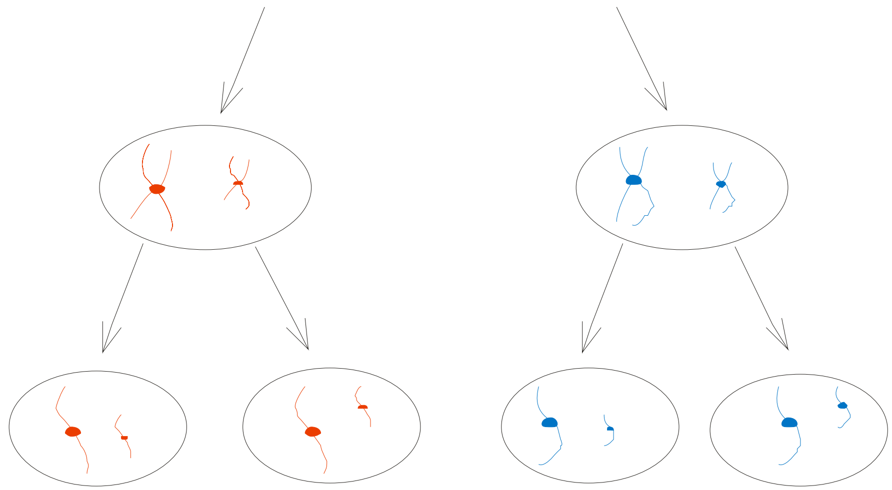
Meiosis (Formation of Gametes)

- Original cell
- Chromosome doubling
- Chromosome pairing (note: crossover occurs here)



Meiosis (Formation of Gametes)

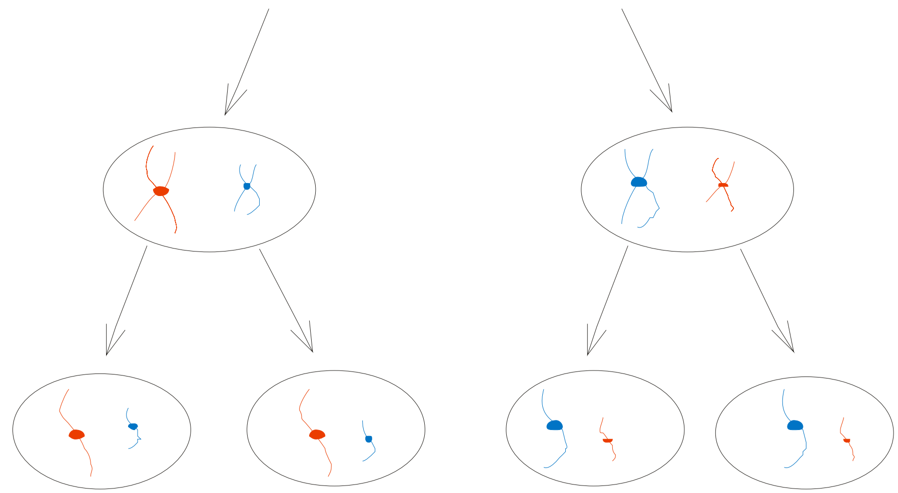
- Cell Division (Possibility 1)
- Another Division
- Each sperm or egg has ½ normal number of chromosomes



Meiosis (Formation of Gametes)

- Cell Division (Possibility 2)

- Another Division



Mendelian Inheritance

- Gregor Johann Mendel
  - 1822-1884
  - Austrian Roman Catholic Monk and Botanist
  - Performed experiments with peas in 1860s
  - Reported work in 1866
  - Work remained unknown for 35 years

An Experiment with Tall and Short Pea Plants

- When tall plant crossed with short plant, he always got a tall plant
- This was true regardless of which parent (male or female) was tall
- This confirmed earlier observations that both parents contribute equally
- He then allowed hybrids to self pollinate.   He ended up with 787 tall plants and 277 short plants

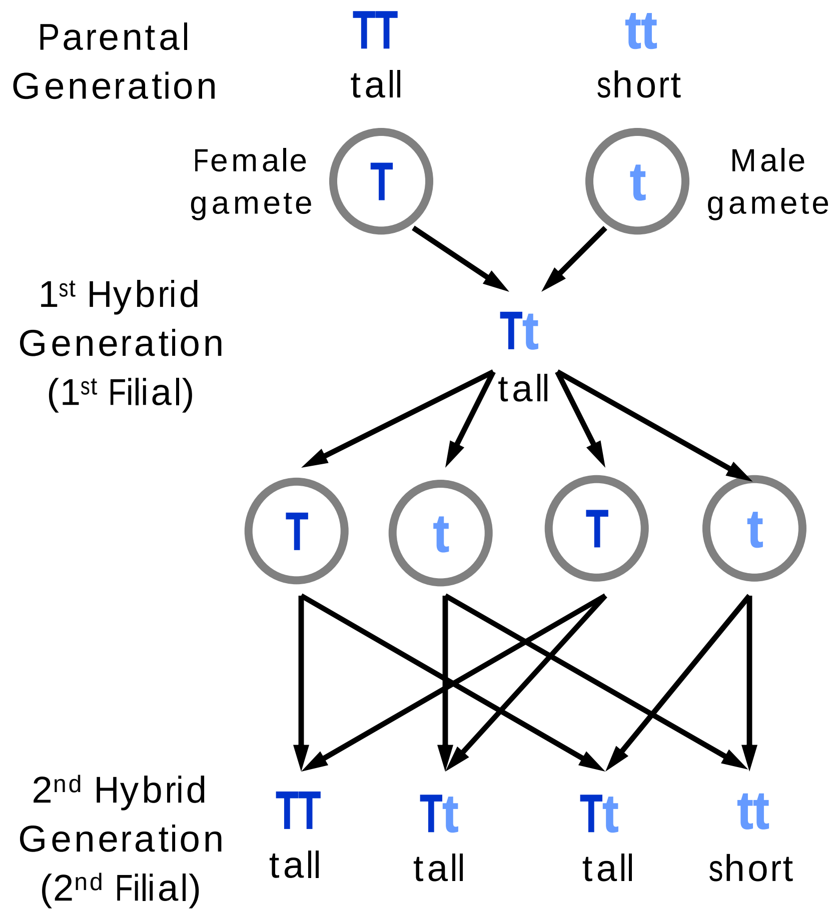
Mendel's First Law : Law of Segregation

> Heredity characteristics (tallness or shortness) occur in pairs and these pair segregate such that only one member of the pair is used in a gamete

- Heredity characteristic unit now known as gene
- Mendel also developed concept of *dominance* and *recessiveness*
- Tested theory using genetic ratios of various mating combinations

Explanation of Results

- Results
  - ¼ Short
  - ¾ Tall
    - Of the tall, 1/3 produced only tall plants when self-fertilized
    - Of the tall, 2/3 produced tall and short plants when self-fertilized



Additional Vocabulary

- Homozygote: zygote with identical genes (TT or tt)
- Heterozygote: zygote with different genes (Tt)
- Alleles: alternate forms of a gene (T or t)
- Genotype: genetic makeup (TT, Tt, tt)
- Phenotype: characteristic determined by genotype (tall or short)

Incomplete Dominance

- Consider color pattern in cattle
- One pair of alleles determines color (complete dominance)
  - BB: black
  - Bb: black
  - bb: red
- Another pair determines extent of color (incomplete dominance)
  - RR: solid color
  - Rr: speckled with white
  - rr: no color

Mechanism for Dominance

- Genes result in production of enzymes
- For complete dominance, one allele produces enough to achieve a desired effect
- Often, there will be subtle differences between homozygous and heterozygous phenotypes (a few white hairs on a black mouse)

Mendel's 2nd Law: Law of independence

The members of one pair of alleles segregate independently of other pairs

- (This is only true if they are on separate chromosomes)

Mendel's 2nd Law: An Example

- Round (R) vs Wrinkled (r) seeds
- Yellow (Y) vs Green (y) seeds
- Round and Yellow are dominant

- Step 1: Cross strain producing round yellow seeds with strain producing wrinkled green seeds
- Result: The F1 seeds are round and yellow
- Step 2: Self fertilize F1 plants
- Result:
  - 9/16 of plants are round and yellow
  - 3/16 of plants are wrinkled and yellow
  - 3/16 of plants are round and green
  - 1/16 of plants are wrinkled and green

Expected Ratios

- Consider shape (if independent)

RR → Rr ← rr

F1 Rr

- Likewise for color (if independent)
  - ¾ yellow
  - ¼ green

F2 RR Rr Rr rr

3/4 round 1/4 wrinkled

Expected Ratios

- Thus, if independent we should have
  - 9/16 round yellow
  - 3/16 round green
  - 3/16 wrinkled yellow
  - 1/16 wrinkled green
- This is what is observed

Gene Interactions:
The Punnett Square

- Consider the comb shape in poultry
- Genotype — Phenotype

Genotype	Phenotype
R- P-	walnut
R- pp	rose
rr P-	pea
rr pp	single

The Punnett Square

	Sperm from RrPp (walnut)				
Egg from RrPp (walnut)		RP	Rp	rP	rp
	RP	RRPP	RRPp	RrPP	RrPp
	Rp	RRPp	RRpp	RrPp	Rrpp
	rP	RrPP	RrPp	rrPP	rrPp
	rp	RrPp	Rrpp	rrPP	rrpp

Epistasis: Genes Masking Other Genes

- Consider mouse coat patterns
- Allele C necessary for any pigment
- Genotype BB and Bb produce black; bb is brown
- Thus
  - C- B- black
  - C- bb brown
  - cc B- white
  - cc bb white
- Allele cc masks the color gene

Mutation

- Occasionally a gene mutates to another allele
- A typical mutation rate for a given gene is one in 10^5 generations
- Since there are many genes (say 10^4) per cell, mutation is pretty common
- In evolutionary terms
  - A high rate weakens population
  - A low rate keeps population from responding to change

Mendel’s Insight

- Used sharply contrasting traits
- Used plants that can be self fertilized
- Used plants that produce large sample sizes
- He was lucky (genes are only independent when on different chromosomes)
- His luck didn’t hold – he tried (unsuccessfully) moving on to hawkweed which has both sexual and asexual reproduction which wasn’t understood for long after his death
- The greatest barrier to acceptance of his theory were traits that are caused by many traits and influenced by environment (example human height and shape)

Linkage and Chromosome Mapping

- Linkage : Genes on the same chromosome tend to stay together in inheritance

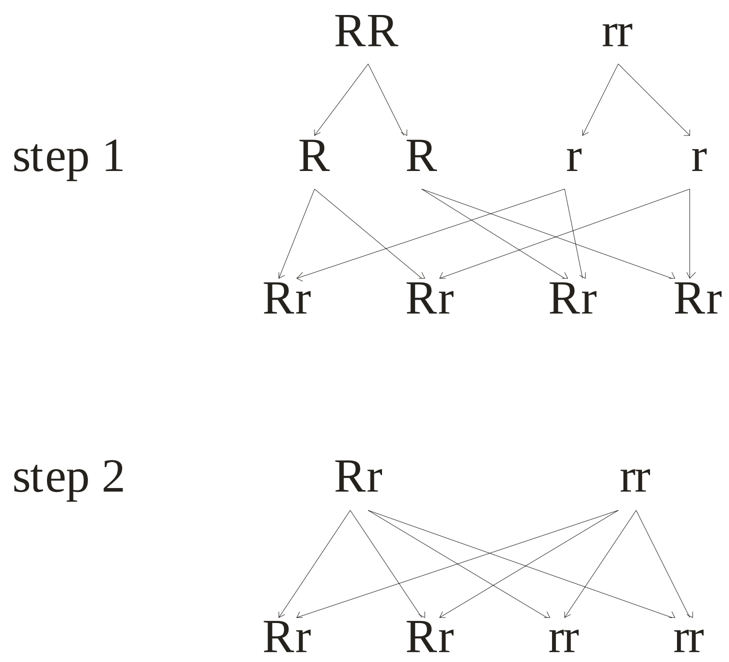
- Consider Poultry
  - Leg length
    - C – creeper (dominant, note CC is lethal)
    - c – normal (recessive)
  - Comb type
    - R – rose comb (dominant)
    - r – single comb (recessive)

Linkage and Chromosome Mapping

- Experiment
  - Step 1: A homozygous rose-combed, normal-legged mated with a single-combed, short-legged strain
  - Step 2: The resulting creeper hybrids test-crossed with single-combed, normal legged strain

Linkage and Chromosome Mapping

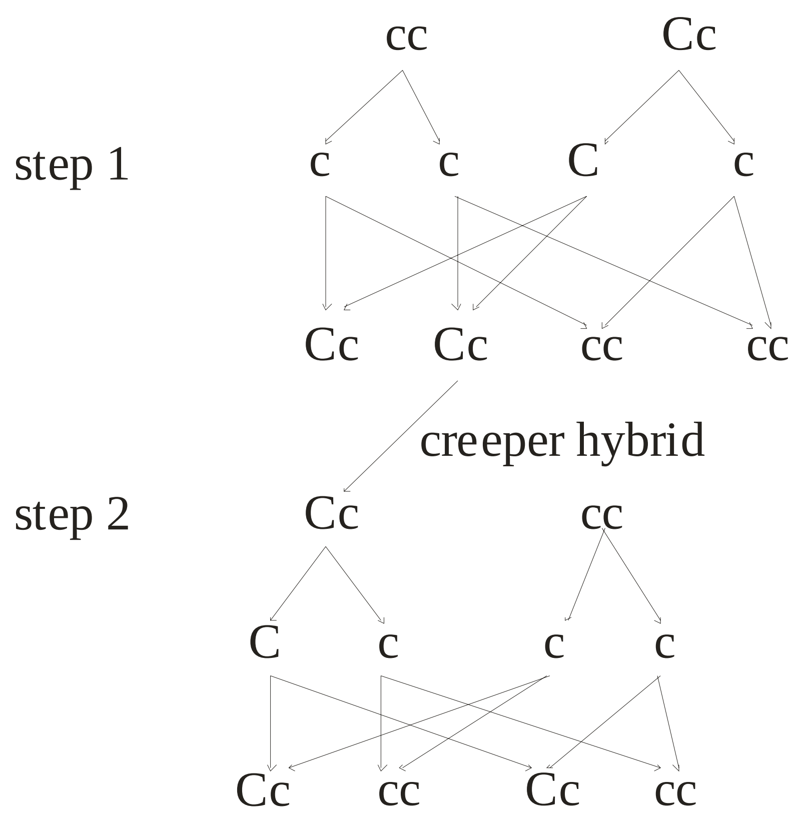
- What should happen (comb)



- Thus 50% rose, 50 % single

Linkage and Chromosome Mapping

- What should happen (legs)



- Thus 50 % short legged, 50 % long legged

Linkage and Chromosome Mapping

- Thus, by Mendelian principles
  - 25% short-legged rose-combed
  - 25% normal-legged rose-combed
  - 25% short-legged single-combed
  - 25% normal-legged single-combed

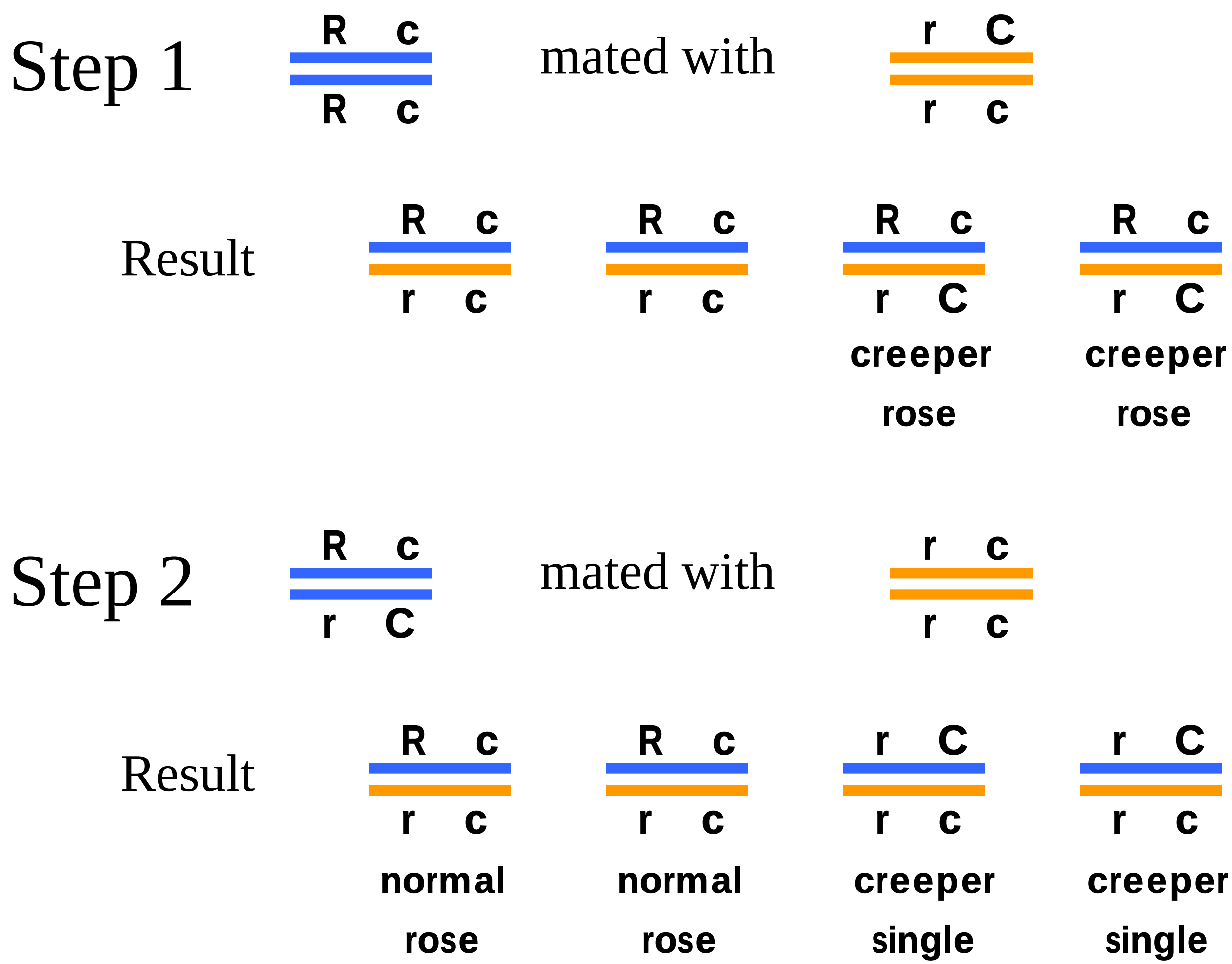
Linkage and Chromosome Mapping

- Actual results

1069 normal rose
1104 short single
6 short rose
4 normal single

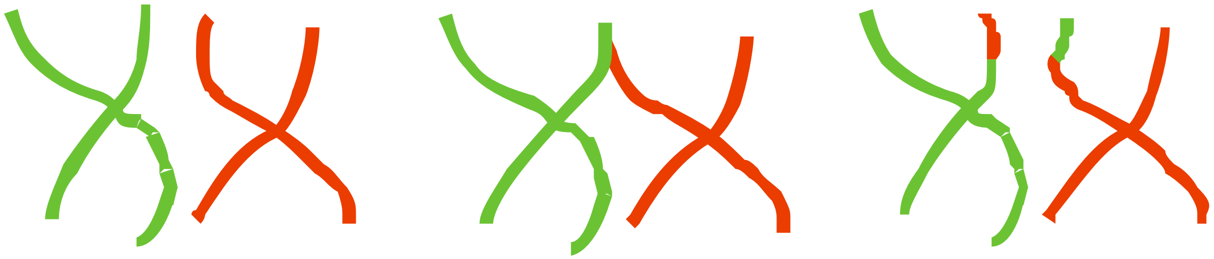
- Explanation: The two alleles were on the same chromosome and did not act independently

Linkage and Chromosome Mapping



Linkage and Chromosome Mapping

- Question:
  - What about the 6 short rose and 4 normal single ?
- Answer:
  - Crossover
- During meiosis the chromosomes can line up side by side and the following can happen:



Linkages and Chromosome Mapping

- Importance of crossover
  - Crossover prevents a beneficial gene from being inseparably linked to deleterious one
  - Crossover provides means for two good genes to get together
  - Extends benefits of sexual reproduction

Inheritance of Quantitative Traits

- Example: height in humans
- Genes that control this are
  - essentially identical to other genes, but not phenotypically identifiable
  - cumulative in effect
  - often influenced by the environment
- This class of traits is said to be polygenic

Inheritance of Quantitative Traits

- Example: Seed color is some species

Genotype	**Phenotype**
A'A'B'B'	very dark red
A'A'B'B,A'AB'B'	dark red
AA'BB',A'A'BB,AAB'B'	medium red
A'ABB,AAB'B	light red
AABB	white