Chemical Biology 03

Dec 9, 2010

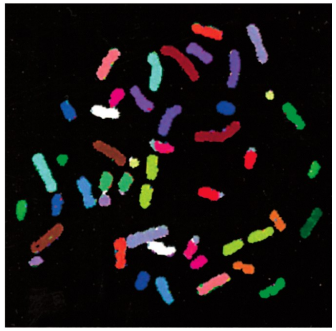
Inheritance II

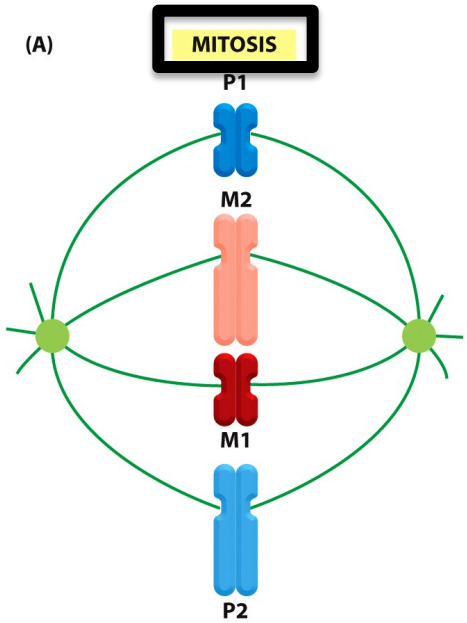
abstract concept and behavior of genes

Mitosis: 2n → 2n

Meiosis: 2n → 1n

Regular cell division (mitosis)
maternal and paternal
chromosomes do not interact

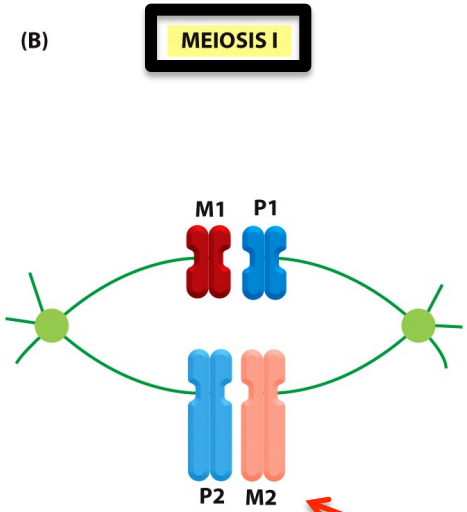




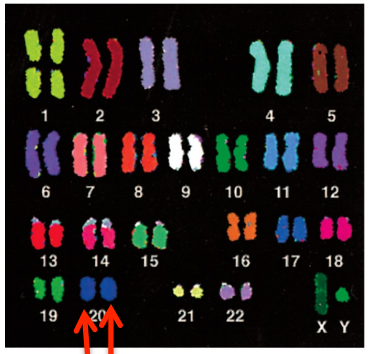
homologous chromosomes
line up at the metaphase plate
independently

Figure 19-6 Essential Cell Biology 3/e (© Garland Science 2010)

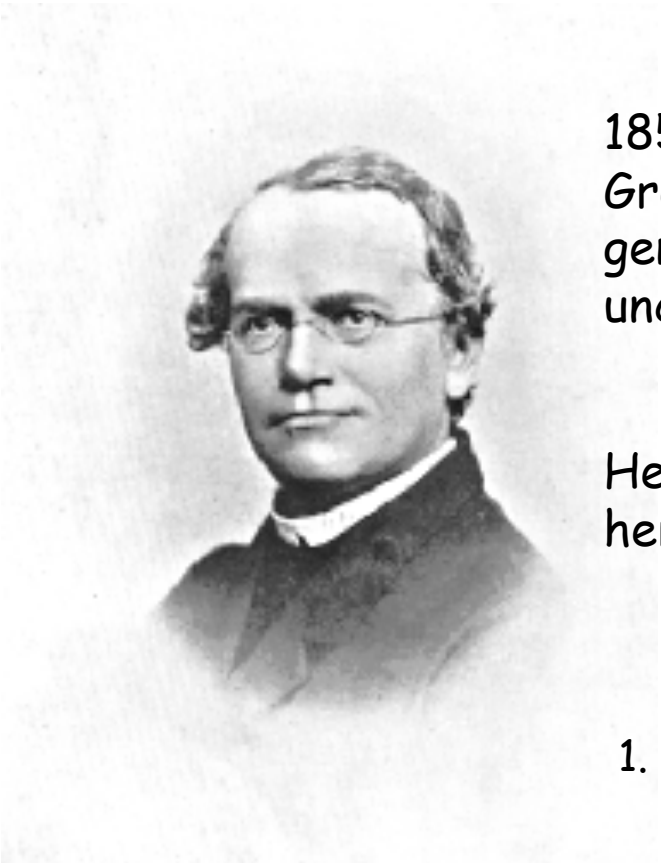
Generation of germ cells (meiosis)
maternal and paternal
chromosomes DO interact



homologous chromosomes
are paired at the
metaphase plate



homologous
chromosomes
(maternal and paternal)



1850s

Gregor Mendel came up with the idea that discrete genetic factors ("genes") exist and are passed unchanged from one generation to another.

He followed the behavior of these abstract units of heredity by observing inheritance of pea plant traits:

1. Each gene can exist in multiple forms ("alleles")

   a A **I^A I^B I^C**

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2. Each individual carries a <u>pair</u> of alleles for each gene

   -two alleles can be the same ("homozygous") **aa** **AA**

   -or different ("heterozygous") **aA**

   the alleles may be co-dominant **I^AI^B**

   OR, in other cases,

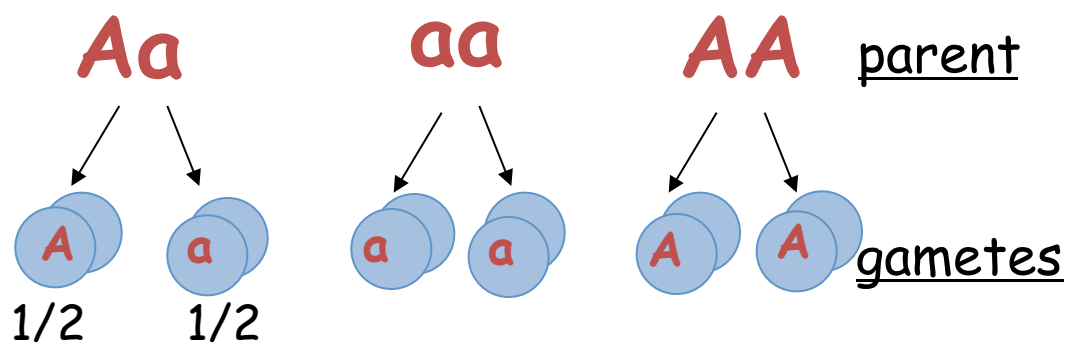
   there may be one dominant and one recessive allele

   Aa

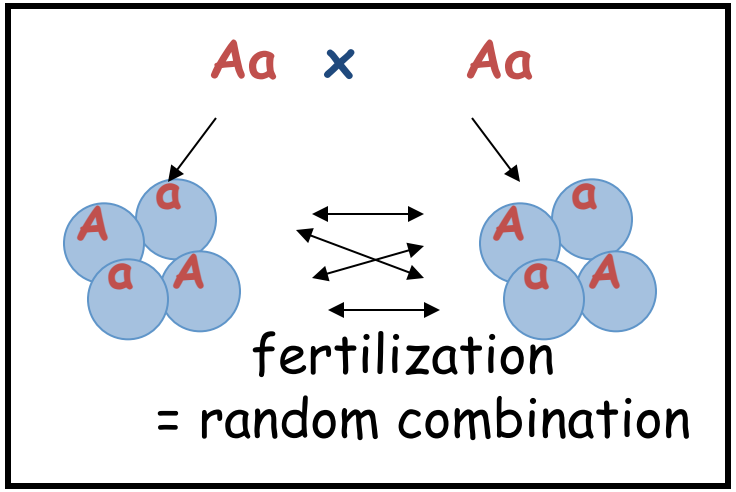
Mendel's First Law of Segregation:

- Each individual carries **a pair** of alleles for each gene

- The two alleles **segregate** from one another during gametogenesis



- Alleles unite at **random** (one from each parent) during fertilization



Using math to predict the outcome of a cross: **Aa × Aa**

Aa → 1/2 **A**; 1/2 **a**
parent 1 gametes

Aa → 1/2 **A**; 1/2 **a**
parent 2 gametes

What is the probability of getting **aa** progeny?

Product Rule:

Probability that two independent events will occur simultaneously = ***product*** of the probability of each event occurring on its own.

Use Product Rule: 1/2 **×** 1/2 = 1/4
(and)

probability that the egg carries **a**

probability that the sperm carries **a**

Using math to predict the outcome of a cross:

$$\boxed{Aa \times Aa}$$

$\downarrow$

What is the probability of getting **Aa** progeny?

Aa $\longrightarrow$ 1/2 **A**; 1/2 **a**

parent 1 gametes

Aa $\longrightarrow$ 1/2 **A**; 1/2 **a**

parent 2 gametes

Sum Rule:

If an event can occur more than one way, the probability of that event is the ***sum*** of the independent probabilities.

Use Sum Rule: (1/2 x 1/2) + (1/2 x 1/2) = 1/2

(or)

probability of egg carrying **A** and sperm carrying **a**

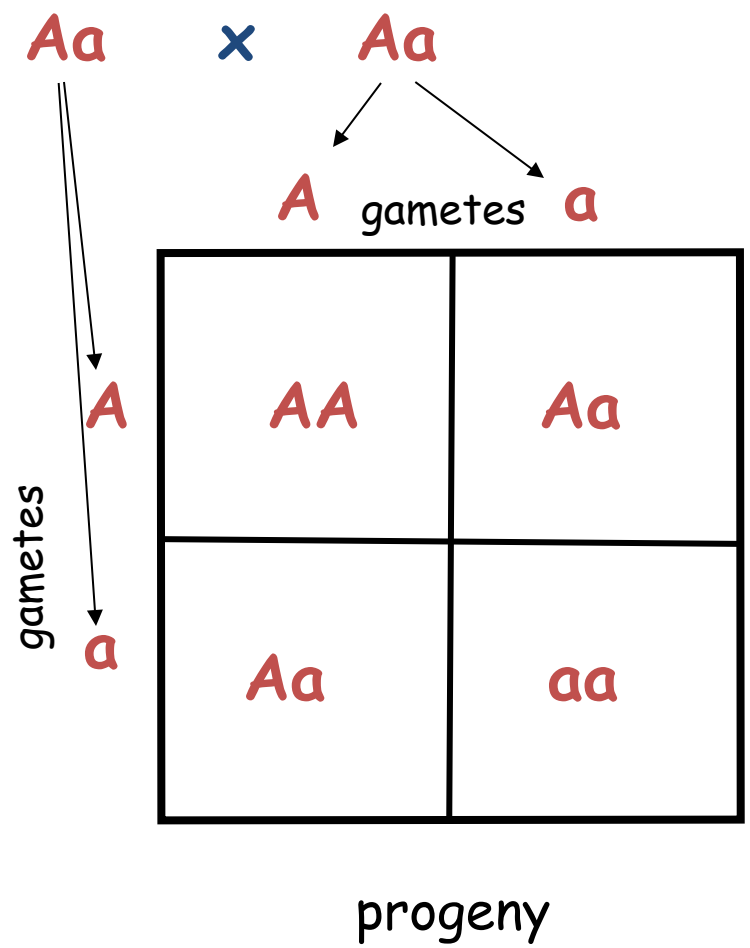
probability of egg carrying **a** and sperm carrying **A**

Visualizing probabilities of potential progeny using the Punnett Square

1. List parent 1's possible gametes across the top (one column for each possible genotype)

2. List parent 2's possible gametes along the left (one row for each possible genotype)

3. Fill in products of fertilization



1/4 homozygous

1/2 heterozygous

1/4 homozygous

Aa × Aa

	A	a
A	AA	Aa
a	Aa	aa

Mendelian Genotype Ratio: 1/4 : 2/4 : 1/4

What about Phenotype Ratio?

Depends on relationship of alleles: Pheno. Ratio

1. dominant and recessive alleles: Aa = AA (___phenotypes) 3/4 : 1/4
2. codominant alleles aa ≠ Aa ≠ AA (___phenotypes) 1/4 : 2/4 : 1/4
3. incomplete dominance: aa < Aa < AA (___phenotypes) 1/4 : 2/4 : 1/4

Most human traits are caused by multiple genes rather than a single gene

However there are 1000s of known human traits (most are rare diseases) that are simple: one gene (= "Mendelian Trait")

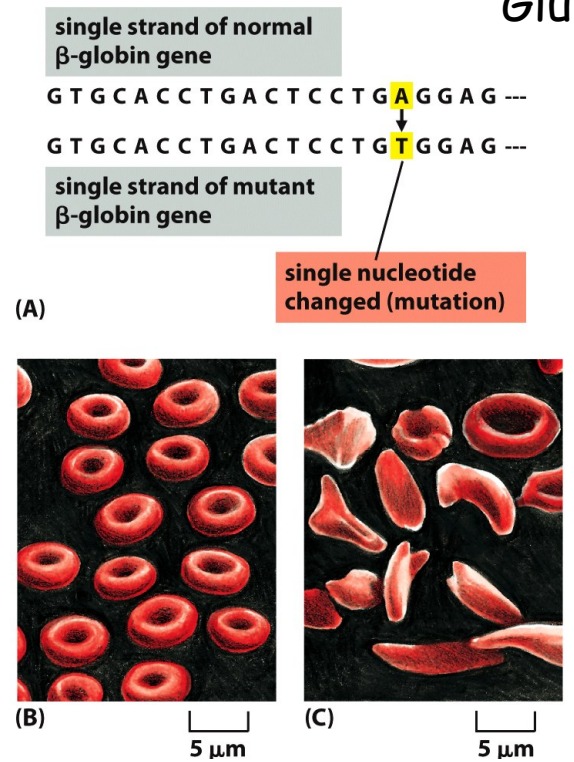
Sickle Cell Anemia
Albinism
Cystic Fibrosis
Hemophelia
Polydactyl
Tay Sachs Disease
Achondroplasia
Huntington's Disease
Phenylketonuria (PKU)
Adenosine deaminase deficiency (ADA)

Glu7->Val

Consider an example:

Sickle Cell Anemia:

caused by one recessive allele of the β globin gene



aa = sc anemia

Aa = healthy (but called "carrier")

AA = healthy

Aa x Aa

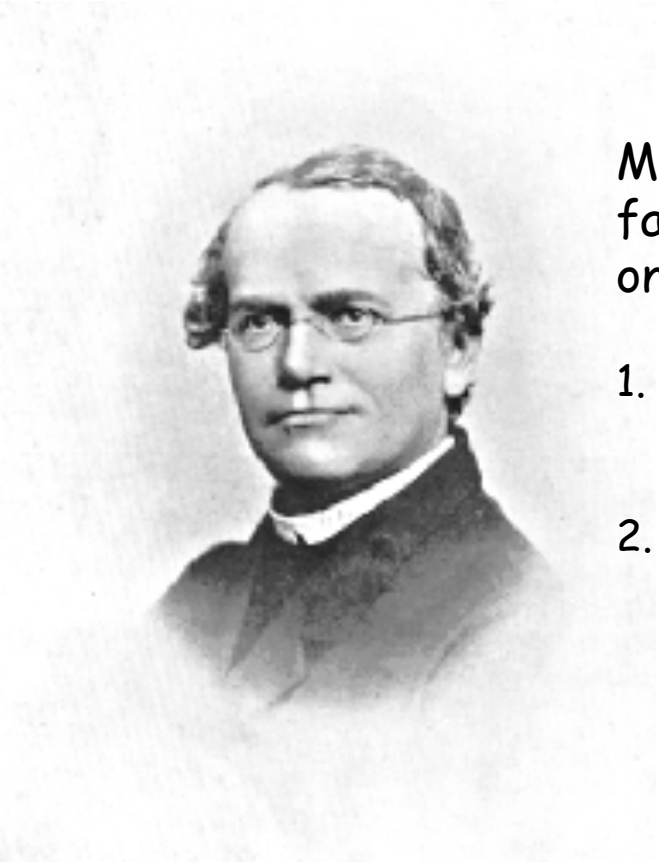
What is the probability of this couple having a child with sc?

What is the probability of having a healthy child?

**What is the probability that their healthy child is a carrier?

Aa x AA

answer same questions as above



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     - the alleles may be co-dominant I^AI^B
       - *OR, in other cases,*
     - there may be one dominant and one recessive allele

Aa

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3. During gametogenesis: alleles are segregated from each other: gametes carry only one allele

Aa
A a

4. Alleles unite at random during fertilization

5. The alleles of different genes behave independently (independent assortment)

5. The alleles of different genes behave independently (independent assortment)

If we follow two genes in a cross, we see that they behave independently of each other; so we simply combine their individual probabilities:

parent	gametes
Aa →	1/2 A; 1/2 a
Bb →	1/2 B; 1/2 b

considering a parent of genotype AaBb , how many different types of gametes are produced and in what proportions?

1/2 A × 1/2 B = 1/4 AB

1/2 A × 1/2 b = 1/4 Ab

1/2 a × 1/2 B = 1/4 aB

1/2 a × 1/2 b = 1/4 ab

Aa Bb x Aa Bb

Aa Bb

Aa Bb

gametes:

1/4	AB
1/4	Ab
1/4	aB
1/4	ab

Aa Bb × Aa Bb

↓

?

Branch Diagram

- Use for multiple genes
- Consider one gene (or one phenotype) at a time
- Combine individual probabilities

A genotype	B genotype	combined
$\frac{1}{4}$ AA	$\frac{1}{4}$ BB	= $\frac{1}{4} \times \frac{1}{4}$ = 1/16 AABB
	$\frac{1}{2}$ Bb	= $\frac{1}{4} \times \frac{1}{2}$ = 1/8 AABb
	$\frac{1}{4}$ bb	= $\frac{1}{4} \times \frac{1}{4}$ = 1/16 AAbb
$\frac{1}{2}$ Aa	$\frac{1}{4}$ BB	= $\frac{1}{2} \times \frac{1}{4}$ = 1/8 AaBB
	$\frac{1}{2}$ Bb	= $\frac{1}{2} \times \frac{1}{2}$ = 1/4 AaBb
	$\frac{1}{4}$ bb	= $\frac{1}{2} \times \frac{1}{4}$ = 1/8 Aabb
$\frac{1}{4}$ aa	$\frac{1}{4}$ BB	= $\frac{1}{4} \times \frac{1}{4}$ = 1/16 aaBB
	$\frac{1}{2}$ Bb	= $\frac{1}{4} \times \frac{1}{2}$ = 1/8 aaBb
	$\frac{1}{4}$ bb	= $\frac{1}{4} \times \frac{1}{4}$ = 1/16 aabb

Aa Bb × Aa Bb

↓

?

Branch Diagram

Last example was done for Genotype
This one is worked out for Phenotype

A dom. phenotype	B dom. phenotype	combined
$\frac{3}{4}$ A phenotype	$\frac{3}{4}$ B phenotype	= 3/4 x 3/4 = 9/16 A_B_
	$\frac{1}{4}$ bb phenotype	= 3/4 x 1/4 = 3/16 A_ bb
$\frac{1}{4}$ aa phenotype	$\frac{3}{4}$ B phenotype	= 1/4 x 3/4 = 3/16 aa B_
	$\frac{1}{4}$ bb phenotype	= 1/4 x 1/4 = 1/16 aa bb