BIOL 1030
Introduction to Biology: Organismal Biology, Spring 2011
Section A

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Classical genetics

The patterns of heredity are all about us. Gregor Mendel (1822-1884) discovered their 'particulate' nature.
To begin, a tiny review . . .

- The Eukaryotic nucleus contains a discreet number of chromosomes containing DNA.
- A gene is a portion of DNA that encodes a specific mRNA for a protein (or other type of RNA, e.g. rRNA).
- Each gene can have many alleles (remember — alternate versions of a gene).
- Each diploid organism inherits two alleles — one from the mother and one from the father.
The pea plant *Pisum sativum* was easy to grow; it develops quickly; it has many offspring, and it has many traits in two forms; plus it is easy to control its mating.
His experimental approach:

1. Stamens (male parts) removed from flowers of short pea plant to prevent self-pollination.
2. Pollen from tall pea plant flower transferred to female part of short pea plant flower.
3. Pod from cross-pollinated plant contains seeds, each representing an independent offspring.
4. Mature plants developed from seeds can reveal inheritance pattern for gene controlling plant height.

He could easily control which plants bred with each other.
Remember alleles, are different versions of the same gene, but . . .

- In many cases - Dominant allele - exerts its effect whenever it is present. Versus a . . .
- Recessive allele - is masked if the dominant allele is present, often because the product is nonfunctional or not even produced.
- The most common allele is not always the dominant one. For example, achondroplasia and Huntington’s alleles are dominant, but rare everywhere; and blue eyes are common in northern Europe, but recessive.
Genotype — an organism's genetic makeup.

* All diploid cells have two alleles per gene corresponding to two homologous chromosomes.
* Homozygous - two identical alleles.
* Homozygous recessive - lower case (tt)
* Homozygous dominant - upper case (TT)
* Heterozygous - one of each - (Tt)
Phenotype - outward expression; What a particular genotype 'looks' like.

For example, in Mendel's peas; each genotype makes the following phenotype:

* TT - tall
* Tt - tall
* tt - short
When he crossed two short plants . . .

He got all short plants in the next generation.
But when he crossed two tall plants . . .

* The results were quite different.
* From some parents he got all tall plants, from others a mix . . . . What was going on?

All tall offspring
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Some tall, some short offspring
And when he crossed tall with short . . .

* The results were also confusing, sometimes yielding all tall, other times a mixture.
* We’ll see why in a moment.
But first lets review some vocabulary.

Genomics is showing us that this is a bit of a misnomer.

**Table 10.1  Miniglossary of Genetic Terms**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generations</strong></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>The parental generation</td>
</tr>
<tr>
<td>F&lt;sub&gt;1&lt;/sub&gt;</td>
<td>The first filial generation; offspring of P generation</td>
</tr>
<tr>
<td>F&lt;sub&gt;2&lt;/sub&gt;</td>
<td>The second filial generation; offspring of F&lt;sub&gt;1&lt;/sub&gt; generation</td>
</tr>
<tr>
<td><strong>Chromosomes and Genes</strong></td>
<td></td>
</tr>
<tr>
<td>Chromosome</td>
<td>A dark-staining body that consists of a continuous double helix of DNA plus associated proteins; each chromosome carries many genes.</td>
</tr>
<tr>
<td>Gene</td>
<td>A sequence of DNA that encodes a protein</td>
</tr>
<tr>
<td>Allele</td>
<td>An alternative form of a gene</td>
</tr>
<tr>
<td><strong>Dominant and Recessive</strong></td>
<td></td>
</tr>
<tr>
<td>Dominant allele</td>
<td>An allele that masks the expression of another allele</td>
</tr>
<tr>
<td>Recessive allele</td>
<td>An allele whose expression is masked by another allele</td>
</tr>
<tr>
<td><strong>Identical or Different Alleles</strong></td>
<td></td>
</tr>
<tr>
<td>Homozygous</td>
<td>Possessing identical alleles of one gene</td>
</tr>
<tr>
<td>Heterozygous</td>
<td>Possessing different alleles of one gene</td>
</tr>
<tr>
<td><strong>Genotypes and Phenotypes</strong></td>
<td></td>
</tr>
<tr>
<td>Genotype</td>
<td>The allele combination in an individual</td>
</tr>
<tr>
<td>Phenotype</td>
<td>The observable expression of an allele combination</td>
</tr>
<tr>
<td>Wild type</td>
<td>The most common phenotype or allele for a gene in a population</td>
</tr>
<tr>
<td>Mutant</td>
<td>A phenotype or allele resulting from a change (mutation) in a gene</td>
</tr>
</tbody>
</table>
Remember, the two alleles of each gene end up in different gametes.

- Start out with TT cross tt (P generation), to produce Tt plants, then he used . . .
- A monohybrid cross, which is the . . .
- Mating between two heterozygotes for a particular gene (mono: one gene, hybrid: mix of allele types).
- The F2 generation has a phenotypic ratio of 3:1 (the way they look, not their genes).
- Similar results were seen by Mendel in seven different pea plant traits.
Here's the seven traits he used.

Table 10.2  *Mendel’s Law of Segregation: Crossing Heterozygotes Produces a 3:1 Phenotypic Ratio*

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Total</th>
<th>Plants Expressing Dominant Allele</th>
<th>Plants Expressing Recessive Allele</th>
<th>Ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Seed form</td>
<td>7324</td>
<td>5474 round (R)</td>
<td>1850 wrinkled (r)</td>
<td>2.96:1</td>
</tr>
<tr>
<td>2. Seed color</td>
<td>8023</td>
<td>6022 yellow (Y)</td>
<td>2001 green (y)</td>
<td>3.01:1</td>
</tr>
<tr>
<td>3. Pod form</td>
<td>1181</td>
<td>882 inflated (V)</td>
<td>299 restricted (v)</td>
<td>2.95:1</td>
</tr>
<tr>
<td>4. Pod color</td>
<td>580</td>
<td>428 green (G)</td>
<td>152 yellow (g)</td>
<td>2.82:1</td>
</tr>
<tr>
<td>5. Flower position</td>
<td>858</td>
<td>651 axial (F)</td>
<td>207 terminal (f)</td>
<td>3.14:1</td>
</tr>
<tr>
<td>6. Seed coat color</td>
<td>929</td>
<td>705 gray (A)</td>
<td>224 white (a)</td>
<td>3.15:1</td>
</tr>
<tr>
<td>7. Stem length</td>
<td>1064</td>
<td>787 tall (L)</td>
<td>277 short (l)</td>
<td>2.84:1</td>
</tr>
</tbody>
</table>

Average = 2.98:1

* Each ratio deviates slightly from the expected 3:1 because inheritance reflects the rules of probability. Repeating each experiment would likely yield slightly different ratios, each very close to 3:1.
And what each looks like.

A “Punnet square” reveals the allele combinations.
As seen here:

* The mother’s contribution is shown along the top; the father’s along the side.

* The resulting combinations are in the square.

* We see the typical 3:1 phenotypic ratio from a monohybrid cross.

**Female parent**

- Tall
- Short

**Male parent**

- Tall
- Short

**Female gametes (1:1)**

- T
- t

**Male gametes (1:1)**

- T
- t

**Tt**

- TT
- Tt
- Tt
- tt

**Genotypic ratio 1:2:1**

1 TT: 2 Tt: 1 tt

**Phenotypic ratio 3:1**

3 tall: 1 short
Short plants had to be tt, but . . .

* Tall plants could be TT or Tt.
* He used a testcross to determine their genotype. That is . . .
* He mated an unknown tall individual with a true breeding homozygous recessive (short) individual.
* The unknown was TT, if the offspring were tall. And the . . .
* unknown was Tt, if half the offspring were tall and half short.
The testcross is shown here.

Mendel was able to determine the genotype of the tall female, depending on the ratio of tall to short offspring!
Mendel’s Law of Segregation

* Two alleles of each gene are packaged into separate gametes.
* They segregate, or move apart from each other, during gamete formation.
* When diploid cells undergo meiosis, homologous chromosomes separate.
* During fertilization, gametes join, carrying one member of each homologous pair.
* And Mendel came up with these principles before anybody knew anything about chromosomes!
Here's an illustration:

1. **Homologous chromosomes**
   - **Parent 1:** Replication in interphase
   - **Parent 2:**

2. **Replication in interphase**
   - **Parent 1:** TT
   - **Parent 2:** TT

3. **Segregates alleles into gametes**
   - **Parent 1:** TT, tt
   - **Parent 2:** TT, TT

4. **Fertilization**
   - Offspring (F₁)
     - (equal probability)

Gametes combine at random.
Segregation is shown here with cystic fibrosis, a recessive trait.

Parents are both unaffected carriers (Cc)

Male parent

Female parent

3:1 ratio!

25% chance of affliction.

Offspring

- Unaffected noncarrier
- Unaffected carrier
- Affected

@Pat Pendarvis
Two genes on different chromosomes are inherited independently.

- A dihybrid cross tracks the inheritance of two genes at once. As with a testcross, start...
- With a P generation of true breeding plants.
- He used RRYY (round yellow seeds) cross rryy (wrinkled green seeds). This makes...
- F1 plants that are all heterozygous (with round yellow seeds). Then the...
- Dihybrid cross uses two heterozygous F1 plants (RrYy x RrYy).
- All four phenotypes come out in F2 plants, with a 9:3:3:1 ratio
This is shown here, and... Results in a 9:3:3:1 F2 phenotype ratio.
The law of independent assortment

- Based on these results, Mendel proposed what we now call the law of independent assortment. That is...

- Alleles of different genes move independently into gametes.

- Alleles for one gene do not influence the segregation of alleles for another gene.

- However, Mendel found some trait combinations that did not yield the expected results (now we know – the genes were too close together on the same chromosome).
Here's how it works.

All due to the random alignment of homologous chromosome during Metaphase I.
Punnet squares become unmanageable with more than just two genes.

Hence the "product rule."

Here both parents are trihybrid (RrYyTt). Therefore, . . .

Multiplying the individual probabilities gives the total probability of the offspring also being a trihybrid: 1 in 8.
Gene expression can appear to alter Mendelian ratios.

* It’s not always as straightforward as Mendel reported. Because...

* Underlying genotypic ratios may be there, but the nature of the phenotype, other genes, or the environment can alter how the traits appear.

* For example: Incomplete dominance.

* The heterozygous phenotype is intermediate between two homozygotes. An example is...

* Red and white flowers making pink flowers.
Incomplete dominance as seen in Snapdragons.

* There is no dominant/recessive dichotomy.
* Both alleles express functional proteins. They are both expressed, so a blending is seen.
Codominance can affect the ratios as well.

* In codominance the...
* Heterozygote fully expresses two different alleles and they are both seen in the offspring independently rather than blended together. An example is...
* ABO blood typing – One gene (called I) has three different alleles, expressed on the surface of red blood cells. $I^A$ and $I^B$ are codominant, $I^i$ is recessive.
* $I^A + I^B$ makes type AB, $I^i + I^i$ makes type O, $I^A + I^i$ makes type A, and $I^B + I^i$ makes type B.
<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Surface antigens</th>
<th>ABO blood type</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I^A I^A$</td>
<td>Only A</td>
<td>Type A</td>
</tr>
<tr>
<td>$I^A i$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I^B I^B$</td>
<td>Only B</td>
<td>Type B</td>
</tr>
<tr>
<td>$I^B i$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I^A I^B$</td>
<td>Both A and B</td>
<td>Type AB</td>
</tr>
<tr>
<td>$ii$</td>
<td>None</td>
<td>Type O</td>
</tr>
</tbody>
</table>
And type A cross type B can result in all these combinations.
Another complication is pleiotropy. It is where one gene can have...

- Multiple phenotypic expressions. And it arises because...
- One protein can be important in different biochemical pathways or affect more than one body part. Examples include...
- Marfan Syndrome – connective tissue protein abnormality that Abe Lincoln may have had.
- Pleiotropic conditions can be difficult to trace through families, because individuals with different subsets of symptoms may appear to have different disorders.
Another famous example of pleiotropy is porphyria variegata. Britain's King George III had lots of problems, they may have all been due to this genetic disease.
And the story can be even more complicated: **Multiple genotypes/identical phenotypes!**

- For example, blood clot formation requires eleven separate biochemical reactions, where a separate gene encodes an essential enzyme for each step - an abnormality in any of the individual genes results in the same outcome - poor clotting.
- And gene products can interact, resulting in a complex interplay of genes, which is called . . .
- Epistasis - where one gene affects the expression of another. As a very simple example . . .
- Male pattern baldness masks the effect of the allele for the “widow’s peak” hairline.
Furthermore, environmental influences and multiple genes can have huge effects.

A neat environmental effect is seen in how the temperature can influence the quantity of pigment molecules in the fur of some animals. For example...

* Siamese cats have darker fur where the body part is colder.
Twin studies are often used to try to tease apart ‘nature versus nurture’ effects.

- Nature is often most important, but nurture certainly matters!
- We see this sort of pattern over and over.
Most traits are actually polygenic!

- The phenotype reflects the activities of more than one gene and their interactions.
- Examples include eye color where multiple genes actually affect the final color, and . . .
- Height and skin color. Traits (phenotypes) can often be plotted on a . . .
- Bell-shaped curve (Normal distribution), such that the range and frequency of the continuum can be seen. And . . .
- Environmental influences can make huge differences!
Both are seen in these class photos, arranged as a distribution.

A shift toward taller students is seen in the 1997 (b.) group versus the 1920 (a.) group.
It's also seen in skin color, here simplified to just three genes.
But human skin color is actually way more complicated than that.

- Several genes are involved in human skin tone variation, at least SLC45A2, SLC24A5 ASIP, MATP, TYR, OCA2, and MC1R. And many more could easily also be involved.

- From: http://en.wikipedia.org/wiki/Human_skin_color

- And the traditional dogma about skin color evolution relating to latitude, UV exposure, and vitamin D production, may be bogus. All sorts of exceptions considerably weaken the hypothesis (e.g. tropical rain forests get very little sun), though it’s still widely held.

- A promising alternative is that human skin color evolved in response to sexual selection. Darwin originally espoused these ideas, and they were considerably promoted by Jared Diamond in “The Third Chimpanzee” (1992).
The entire topic is so emotion laden that not all that much work has really been done on it. Regardless, here's the UV/vitamin D view in a couple of pretty well-balanced videos.

- Nina Jablonski has done some of the best work on it. Both of these videos feature her work:
  - [http://www.youtube.com/watch?v=7d9M7HGFX8E](http://www.youtube.com/watch?v=7d9M7HGFX8E)
- And the full text of a review article by her: [http://www.appalachianbioanth.org/jablonski.pdf](http://www.appalachianbioanth.org/jablonski.pdf)
- We'll take the time to check out the TED.com one.
Next time we’ll apply all these principles of classical genetics specifically to ... the human organism.