From time immemorial, people have bred plants and animals for specific purposes.

Early Americans had bred Maize from native grasses.

Even without an understanding of the mechanism of heredity, early breeders were able to breed desired characteristics with great skill...

By the nineteenth century there was intense interest in working out the laws of heredity. However the results were confusing and little progress could be made. No matter! As long as breeders could still breed by the old, intuitive methods, there was no real problem. Then, in 1859, Charles Darwin published “On the Origin of Species”. And that demanded an answer to the age-old question!
According to biblical tradition, the earth and all of its creatures were created around 6000 years ago. They have not changed since the creation.

In 1664, Archbishop James Ussher used scripture to calculate that the Earth was created on October 26, 4004 BC at, umm, 9:00 in the morning. Yes, Harrumph!

But intense study of nature suggested that life had indeed changed over time. Erasmus Darwin, Charles's own grandfather wrote about it in rhyming couplets in 1795!

Roses are red,
Violets are blue.
Life has evolved, and so did you too.
Oooh! Jolly good that.

A more serious effort was made by the Frenchman Jean Baptiste Pierre Antoine de Monet, chevalier de Lamarck (sheesh!) in 1809. Trained as a botanist, Lamarck was assigned to work on invertebrates at the Natural History Museum in Paris.

"Zeas iss Merde!!! Some of zeas sings are quite complex, but others are barely alive! and everything in between! How do I make sense of zeas...? Un moment!... Sacre Bleu!.... Mon Dieu!!!"

"Zeas can all be explained if all organisms have a past developmental history. If I am correct, zen each living organism should be traceable back in time to a point at which it appeared by.... by.... by... spontaneous generation. Oui! Spontaneous generation. While each organism has its own history, none share a common path. More complex organisms arose by spontaneous generation farther back in the past!"

But how could zeas have happened?

Je ne sais pas!
Lamarck eventually came up with a 3-point explanation of how organisms change:

1. spontaneous generation,
2. a vital force argument that all living matter has an inherent will to progress, and, most importantly,
3. inheritance of acquired characteristics. That is, that the new traits acquired in one generation by use and disuse could be inherited by the next generation.

The giraffe is often used as an example of how Lamarckian inheritance of acquired characteristics would work....

uunnggh... if I can just stretch my neck a bit more, then my kids won’t have to work so hard....

According to Lamarck, as the environment changes, species change in response by virtue of the will to progress and the inheritance of acquired characteristics.

And so the situation remained until 1831 when young Charles Darwin set sail on his famous 5-year voyage around the world on board HMS Beagle....

Blaaaachhhh

He suffered from terrible seasickness...

Darwin drew four conclusions from his extensive travels in South America and the Galapagos islands....

1. The raising of the South American continent shows that the earth is very ancient
2. Fossil animals are found in the same place where related, but different species now live
3. Living species are replaced by different, but related species in adjacent geographical regions
4. Species on islands are unusual, but closely related to those on the nearest continental land mass

And #5! Don’t forget #5!...Never, ever go to sea again!!!

and he never did...

Over the next 20 years, Darwin recorded his observations and conclusions in a series of notebooks...

I think....
that all life is linked by common descent.
There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms, most beautiful and most wonderful have been, and are being, evolved*

*On The Origin of Species, 1st ed.
Darwin, like Lamarck before him, saw that species **changed** over time.

But while Lamarck **believed** that each line was **separate** and **unique**, Darwin thought that all species, living and extinct, were **interconnected** in a complex branching chain.

One evening, Darwin decided to take his mind off his problems by reading Thomas Malthus's essay "On Population" when....

Yes!!! Of Course! Malthus just saved my butt!!

In every generation there are more individuals born into society than society can support. Therefore, it is important to have a good war now and again to thin out the ranks of the lower classes.

Similarly, there are more organisms born into the world than the **environment** can support. Why the **progeny** of just one fish, unchecked, would fill the oceans in just a few generations. There must be a tremendous **struggle for survival** in which only the **fittest** survive. Fitness is measured not in terms of size or strength, but in the ability to **reproduce**. In each generation, there are individuals with variant characters - some good, some bad. The environment exerts **selection** in favor of the good variants and against the bad so that over time, the new, good variation spreads throughout the population. I call this phenomenon "**natural selection.**"

Applying Darwin's theory of **natural selection** to Lamarck's giraffes, we see generation, most would have an average neck length, but some **spontaneous** shorter, and others longer. If the **environment** were to change such were **favored**, then the shorter forms would die off because they disadvantage. Over several **generations**, all giraffes would now spread through the population.

Both Lamarck and Darwin saw the **environment** as the main **determiner** of **evolution**, but each saw the role of the environment differently.
According to Lamarck, changes in the environment directly induced changes in species through the combined action of the inherent will to progress and the inheritance of acquired characteristics.

But according to Darwin, the environment exerts its effects indirectly. Variation occurs regardless of the environment. As the environment changes, those that happen to be best adapted are more successful and survive to reproduce, so passing those variations on to their offspring. But the environment is fickle. At a later time, the environment could change so as to favor the opposite variation. Darwin saw evolution as a random and undirected process.

Darwin studied the matter for many years, becoming an accomplished pigeon and plant breeder in the process. He called his final solution to the problem of heredity Pangenesisis. According to Pangenesisis, each organ and tissue in the body produced these unseeable little thingies that he called gemmules. Gemmules representing each tissue were present in the seminal fluids of male and female, and they mixed at conception. Thus, each offspring was a blend of its parents' gemmules. That's why children have the combined traits of both parents. Yes! of course!

But Darwin's ideas about Pangenesisis and heredity received a considerable amount of criticism - most notably from the engineer Henry Charles Fleeming Jenkin....

Hey Chuck, you got it wrong! Pangenesisis and Natural Selection contradict each other!

Fleeming Jenkin presented his argument in a typical 19th century racist comparison of whites and blacks. Let's use a more PC example of antler size in deer...

In deer, big antlers....well, uh, score...

But suppose a new variant with larger antlers should appear.....

Hey!!

Oooh, is he racked!

one at a time, girls, one at a time

well, naturally he'll get all the chicks - er does - and breed disproportionately more than the other guys!

Darwin, by the way, called this type of natural selection "sexual selection"
...and over several generations, the new trait will spread through the population and all of the bucks will have larger antlers.

If Panggenesis is about blending, and the only gemmules available for that first big antlered variant are normal gemmules, then his son would have intermediate antlers. And if his son mates with normal females, then his son's antlers would become smaller until...

...eventually over several generations, the new variant would regress to normal size - exactly the opposite of what Darwin predicted by Natural Selection!

According to Fleeming Jenkin, Panggenesis and Natural Selection were mutually exclusive!

Darwin accepted Fleeming Jenkin's argument and he put his trust in Panggenesis. Thus, in later editions of *The Origin* he backed farther and farther away from Natural Selection:

1st ed - Natural Selection is the mechanism of evolution
4th ed - Natural Selection is an important mechanism of evolution
6th ed - Natural Selection is one mechanism of evolution

In the end, Darwin retreated to Lamarck's inheritance of acquired characteristics to explain genetic change.

So who was this Mendel character?

What did he know that Darwin didn't?

Could he have helped Darwin out with that Fleeming Jenkin thing?

*Actually, he did, but, unfortunately, posthumously for both men.
Mendel’s life was the stuff of scientific legend. He was born to a poor peasant family in Moravia, but one that valued education and appreciated the advantages that it could give to young Johann. His teachers recognized him as a gifted student and arranged for him to attend a gymnasium. Family hardships prevented him from attending university, so Mendel’s teachers arranged for him to enter the Augustinian monastery of St. Thomas in Brno, where he adopted his monastic name, Gregor.

A monastery might seem like an odd choice for a scientifically gifted man like Mendel, but St. Thomas was an unusual monastery. The community was dedicated to teaching, and the brothers were encouraged to pursue art, philosophy, and scientific research. The order ultimately sent Mendel to Vienna to study at the university. Throughout his education, Mendel showed an interest and talent in mathematics, physics, and botany. In addition to his teaching responsibilities, he pursued research in meterology and plant breeding. He ultimately became the much beloved abbot of the monastery.

Our interest here, is Mendel’s work with the garden pea, *Pisum sativum*. Mendel was interested in understanding the laws that govern the formation of hybrids.

Mendel began his famous pea experiments in 1856. Over a period of eight years, he grew tens of thousands of pea plants in his tiny monastery garden.

Mendel used a very modern, reductionist approach to his research...

Hmff! Others have tried to sort out the laws of hybrids and failed. My approach will be different. Rather than studying complex traits, I will look at a few very simple characters that always breed true, and then subject my results to rigorous mathematical analysis.

And in 1865 he presented his research to the Natural Science Society of Brno.

<table>
<thead>
<tr>
<th>Inheritance Factor</th>
<th>Traits</th>
<th>Test Cross Results</th>
<th>F2 Values (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mixed Parent</td>
</tr>
<tr>
<td>1. Shape of seed round (R) and wrinkled (r)</td>
<td>560 (R)</td>
<td>3774 (R)</td>
<td>184 (r)</td>
</tr>
<tr>
<td>2. Colour of cotyledons yellow (Y) and green (y)</td>
<td>1050 (Y)</td>
<td>863 (Y)</td>
<td>202 (y)</td>
</tr>
<tr>
<td>3. Colour of flower purple (P) and white (p)</td>
<td>1182 (P)</td>
<td>793 (P)</td>
<td>389 (p)</td>
</tr>
<tr>
<td>4. Stem color brown (S) and white (s)</td>
<td>112 (S)</td>
<td>710 (S)</td>
<td>41 (s)</td>
</tr>
<tr>
<td>5. Flower position erect (E) and drooping (e)</td>
<td>112 (E)</td>
<td>710 (E)</td>
<td>41 (e)</td>
</tr>
<tr>
<td>6. Presence of tendril (T) and absence (t)</td>
<td>112 (T)</td>
<td>710 (T)</td>
<td>41 (t)</td>
</tr>
<tr>
<td>7. Flower position erect (S) and drooping (s)</td>
<td>112 (S)</td>
<td>710 (S)</td>
<td>41 (s)</td>
</tr>
</tbody>
</table>
...and the results of my mathematical analysis are quite clear. The inheritance of hybrid traits closely follows the well-known law of pairs. From this we can infer that each hereditary trait is governed by a pair of factors. Thus, in a monohybrid cross we find the ratio of F2 progeny to be 3:1... and in a dihybrid cross we find the ratio of F2 progeny to be 9:3:3:1... and in a trihybrid cross, we find the ratio of F2 progeny to be 27:9:9:9:9:9....

*Today the law of pairs is known as the binomial expansion. We'll hear much more about this in class.

At reproduction these factors segregate away from each other such that each parent contributes only one of the pair to its progeny. I call this the law of random segregation. When working with multiple traits, we see that the several factors assort independently of one another. I call this the law of independent assortment. Curiously, some factors are able to mask the effects of their partner factor. I call this phenomenon dominance and recessiveness.

Mendel encouraged Mendel to extend his research to other plants by studying Hawkweed, Hieracium pilosella, Nageli's own pet research plant. What a mistake that was!

Mendel's research depended on careful artificial pollination between selected plants. But nobody knew that hawkweed reproduced asexually. The problem was that it required pollen to stimulate seed development but the pollen did not actually contribute any of its own traits to its progeny. So of course, Mendel obtained screwy, inconsistent results.

Mendel's paper languished for 34 years until, in 1900, it was simultaneously discovered by Hugo de Vries, Carl Correns, and Erich von Tschermak. All three were working on problems similar to Mendel's. The difference was that they were able to recognize the significance of the work where Mendel's contemporary, and even Mendel himself, could not. 1900 thus marks the beginning of Genetics, with Mendel as the recognized founder.

**Versuche über Pflanzen-Hybridren (1865)**

von Gregor Mendel

(1) Einleitende Bemerkungen

Künstliche Befruchtungen, welche an Zierpflanzen deshalb vorgenommen wurden, um neue Farben-Varianten zu erzielen, waren die Veranlassung zu den Versuchen, die hier beschrieben werden sollen. Die aufgefundenen Vorteile der dieselben Hybridformen sind nun von den bisherigen unverrückbaren. Ob die Anregung zu weiteren gleichen Arbeiten gesteckt, ob die Entwicklung der neuen Pflanzenzeug. Deren Aufgabe war die Entwicklung der neuen Pflanzenzeug.