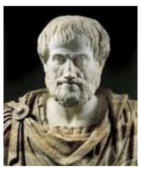
The Debate Over Spontaneous Generation

Science is an ever changing field of study. New technology and experiments can completely change what we thought we knew about a certain topic. People have always based their beliefs and theories on what they see going on in the world around them. Before microscopes could show cells and microorganisms, we didn't even know they existed. As technology and understanding get better, we are able learn more and sometimes our theories change completely. An example of a strong scientific theory that has been proven to be incorrect is spontaneous generation.



For example, since at least the time of **Aristotle** (**400 BC**), people believed that simple living organisms could come into being by **spontaneous generation**. This was the idea that non-living *objects* can give rise to living *organisms*. People of that time period believed that simple organisms like worms, beetles, frogs, and salamanders could appear dust, mud, rotten food etc.

Example: Every spring, the Nile River flooded areas of Egypt along the river, leaving behind nutrient-rich mud that enabled the people to grow that year's crop of food. However, along with the muddy soil, large numbers of frogs appeared that weren't around in drier times.

What they thought then: frogs come from muddy soil

What we know now: frogs can "hibernate" in dry soil. When it rains, it signals them to come out in large numbers to reproduce.

Example: In many parts of Europe, medieval farmers stored grain in barns with thatched roofs (made of straw). As a roof aged, it was not uncommon for it to start leaking. This could lead to spoiled or moldy grain, and of course there were lots of mice around.

What they thought then: It was obvious to them that the mice came from the moldy grain.

What we know now: The grain provides a good food source for mice which draws them to the moldy grain. Once there, they begin to reproduce.

Example: In the cities, there were no sewers or garbage trucks. Sewage flowed in the gutters along the streets, and the sidewalks were raised above the streets to give people a place to walk. In the morning, the contents of the chamber pots were tossed out the nearest window. When people were done eating a meal, the bones were tossed out the window, too. Most of these cities also had major rat problems which contributed to the spread of Bubonic Plague (Black Death) — hence the story of the Pied Piper of Hamelin, Germany.

What they thought then: The sewage and garbage turned into the rats.

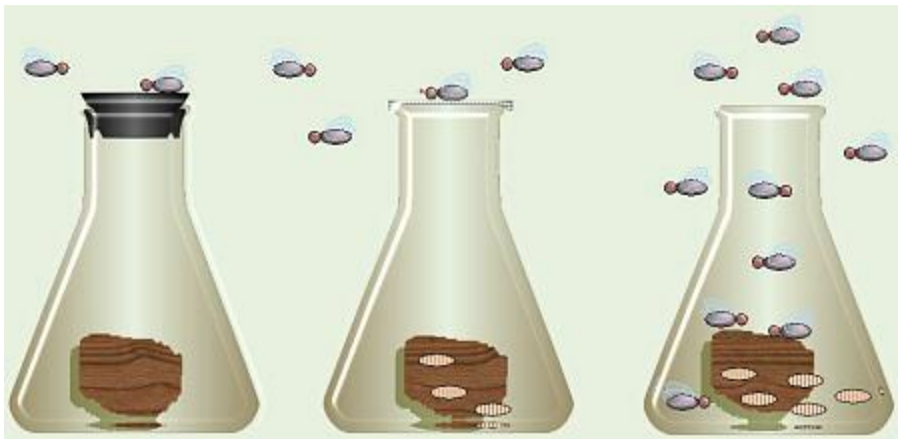
What we know now: The rotting food and liquid attracted the rats to the area. Once there, they would reproduce.

Example: Since there were no refrigerators, the mandatory, daily trip to the butcher shop, especially in summer, meant battling the flies around the carcasses. Typically, carcasses were "hung by their heels," and customers selected which chunk the butcher would carve off for them.

What they thought then: Obviously, the rotting meat that had been hanging in the sun all day was the source of the flies.

What we know now: The flies are attracted to the meat as a place to lay their eggs. The eggs then hatch into maggots

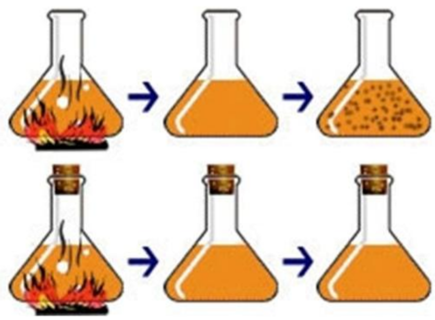
In **1668, Francesco Redi**, an Italian physician, did an **experiment** with flies and wide-mouth jars containing meat. This was a true scientific experiment — many people say this was the first *real* experiment.



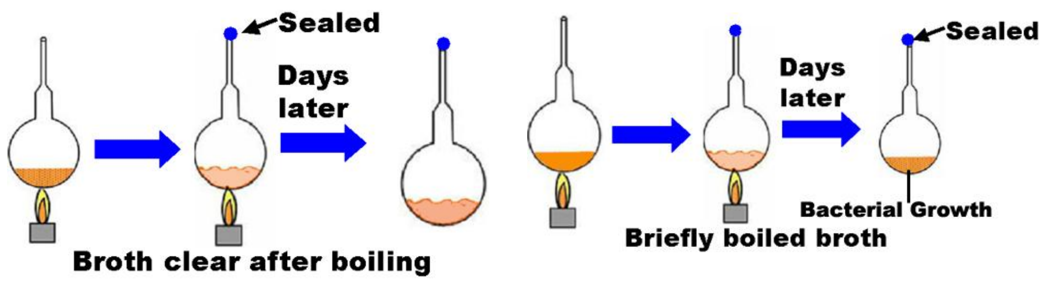
1. **Observation:** There are flies around meat carcasses at the butcher shop.
2. **Question:** Where do the flies come from? Does rotting meat turn into or produce the flies?
3. **Hypothesis:** Rotten meat does not turn into flies. Only flies can make more flies.
4. **Prediction:** If meat cannot turn into flies, rotting meat in a sealed (fly-proof) container should not produce flies or maggots.
5. **Testing:** Wide-mouth jars each containing a piece of meat were subjected to several variations of "openness" while all other variables were kept the same.
    - **control group** — These jars of meat were set out without lids so the meat would be exposed to whatever it might be in the butcher shop.
    - **experimental group(s)** — One group of jars were sealed with lids, and another group of jars had gauze placed over them.
    - **replication** — Several jars were included in each group.
6. **Data:** Presence or absence of flies and maggots seen in each jar was recorded. In the control group of jars, flies were seen entering the jars. Later, maggots, then more flies were seen on the meat. In the gauze-covered jars, no flies were seen in the jars, but were observed around and on the gauze, and later a few maggots were seen on the meat. In the sealed jars, no maggots or flies were ever seen on the meat.
7. **Conclusion(s):** Only flies can make more flies. In the uncovered jars, flies entered and laid eggs on the meat. Maggots hatched from these eggs and grew into more adult flies. Adult flies laid eggs on the gauze on the gauze-covered jars. These eggs or the maggots from them dropped through the gauze onto the meat. In the sealed jars, no flies, maggots, nor eggs could enter, thus none were seen in those jars. Maggots arose only where flies were able to lay eggs. This experiment disproved the idea of spontaneous generation for larger organisms.

After this experiment, people were willing to acknowledge that organisms didn't arise by spontaneous generation, but had to have parents. With the development and refinement of the microscope in the 1600s, people began seeing all sorts of new life forms such as yeast, fungi, bacteria, and various protists. No one knew from where these organisms came, but people figured out they were associated with things like spoiled broth. This seemed to add new evidence to the idea of spontaneous generation — it seemed perfectly logical that these minute organisms should arise spontaneously.

In **1745 - 1748, John Needham**, a Scottish clergyman and naturalist showed that microorganisms flourished in various soups that had been exposed to the air. He claimed that there was a "life force" present in the molecules of all inorganic matter, including air and that could cause spontaneous generation to occur, thus accounting for the presence of bacteria in his soups. He even briefly boiled some of his soup and poured it into "clean" flasks with cork lids, and microorganisms *still* grew there.

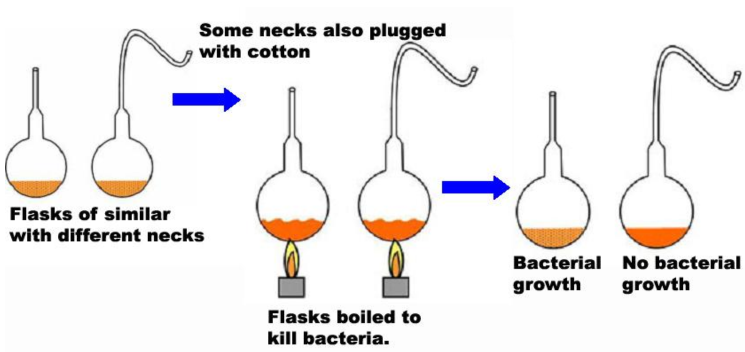


A few years later **(1765 - 1767), Lazzaro Spallanzani**, an Italian biologist, tried several variations on Needham's soup experiments. First, he boiled soup for one hour, then sealed the glass flasks that contained it by melting the mouths of the flasks shut. Soup in those flasks stayed sterile. He then boiled another batch of soup for only a few minutes before sealing the flasks, and found that microorganisms grew in that soup. In a third batch, soup was boiled for an hour, but the flasks were sealed with corks (which let some air in), and microorganisms grew in that soup. Spallanzani concluded that while one hour of boiling would sterilize the soup, only a few minutes of boiling was not enough to kill any bacteria initially present, and the microorganisms in the flasks of spoiled soup had entered from the air.



This initiated a heated argument between Needham and Spallanzani over sterilization (boiled broth in closed vs. open containers) as a way of refuting spontaneous generation. Needham claimed that Spallanzani's boiling used to sterilize the containers had killed the "life force." He felt that bacteria could not develop (by spontaneous generation) in the sealed containers because the life force could not get in, but in the open container, the broth rotted because it had access to fresh air, hence the life force inherent in its molecules, which contained and replenished the life force needed to trigger spontaneous generation. In the minimally-boiled flasks, he felt the boiling was not severe enough to destroy the life force, so bacteria were still able to develop.

Louis Pasteur ended the debate in **1864** with his famous swan-neck flask experiment, which allowed air to contact the broth. Microbes present in the dust and air were not able to navigate the bends in the neck of the flask.



1. **Observation(s):** From Needham's and Spallanzani's experiments, it was known that soup that was exposed to the air spoiled — bacteria grew in it. Containers of soup that had been boiled for one hour, and then were sealed, remained sterile. Boiling for only a few minutes was not enough to sterilize the soup. Pasteur had previously demonstrated that the dust collected by drawing air through a cotton ball contained large numbers of bacteria, hence he knew that bacteria were present in the air and could be filtered out by using a cotton ball. He also knew that bacteria would settle out on the walls of a long, bent, glass tube as air was passed through it.
2. **Question:** Is there indeed a "life force" present in air (or oxygen) that can cause bacteria to develop by spontaneous generation? Is there a means of allowing air to enter a container, thus any life force, if such does exist, but not the bacteria that are present in that air?
3. **Hypothesis:** There is no such life force in air, and a container of sterilized broth will remain sterile, even if exposed to the air, as long as bacteria cannot enter the flask.
4. **Prediction:** If there is no life force, broth in swan-neck flasks should remain sterile, even if exposed to air, because any bacteria in the air will settle on the walls of the initial portion of the neck. Broth in flasks plugged with cotton should remain sterile because the cotton is able to filter bacteria out of the air.
5. **Testing:** Pasteur boiled broth in various-shaped flasks to sterilize it, then let it cool. As the broth and air in the containers cooled, fresh room air was drawn into the containers. None of the flasks were sealed — all were exposed to the outside air in one way or another.

control group — Some flasks opened straight up, so not only air, but any bacteria present in that air, could get into them.
experimental group(s) — Pasteur used some flasks with long, S-shaped necks (swan-neck flasks) and closed others with cotton plugs. This allowed air to enter these flasks, but the long, swan neck or the cotton balls filtered out any bacteria present in that air. He subsequently broke the long necks off some of the swan-neck flasks.
replication — Pasteur used several flasks in each of his groups. According to one freshman biology text, some of his original flasks, on display (in France), still are sterile.

6. **Data:** Broth in flasks with necks opening straight up spoiled (as evidenced by a bad odor, cloudiness in previously clear broth, and microscopic examination of the broth confirming the presence of bacteria), while broth in swan-neck flasks did not, even though fresh air could get it. Broth in flasks with cotton plugs did not spoil, even though air could get through the cotton. If the neck of a swan-neck flask was broken off short, allowing bacteria to enter, then the broth became contaminated.
7. **Conclusion(s):** There is no such life force in air, and organisms do not arise by spontaneous generation in this manner. To quote Louis Pasteur, "Life is a germ, and a germ is Life. Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment."

Spontaneous Generation was finally put to rest as a theory for the creation of smaller organisms.

Activity-Recreation of Pasteur's Experiment

Materials Needed

- low-salt broth (chicken or beef, home-made or purchased)
- 2 250-mL Erlenmeyer flasks
- 2 1-hole rubber stoppers with bent glass tubing inserted (see diagram)

Procedure

A. Students should work in teams of 2 to 3 people. Each team should perform the following steps.
B. Mark Erlenmeyer flasks accordingly:
    1. flask with stopper and glass tube going straight up
    2. flask with stopper and glass tube bent in S-curve
C. Place about 50 mL of broth in each Erlenmeyer flask.
D. Place appropriate lids on flasks.
E. Boil broth in flasks with appropriate lids on them for 30 min., then let cool.
F. For the next several lab periods, observe the flasks and record any changes in color, turbidity, smell, etc.