

Spontaneous Generation:

Investigation of Microbiology and Controlled Experimentation

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Introduction

Spontaneous generation is similar to other scientific theories in that it has been discussed in philosophy, religion, and science over many centuries since the Ancient Greek civilization thrived. Aristotle was the first philosopher who clearly defined spontaneous generation and what life forms it entails. His idea carried significant weight in scientific, philosophical and religious discourse until the seventeenth century when controlled scientific experiments began to determine scientific thought rather than mere observations. During this time, the science of microbiology was discovered and re-spawned the spontaneous generation theory on the micro level. Scientists during the next 300 years would try either to prove or disprove this theory depending on their beliefs or queries.

Aristotle's Influences

Aristotle seemed to be born specifically to pursue scientific studies. The son of Nicomachus and Phaestis, he was born in Stagira in 384 B.C.E. His father, Nicomachus, was physician to Amyntas III, the king of Macedon. Nicomachus was a member of the guild of Asclepiads, also known as the sons of Asclepius. Asclepius was the founder of medicine who was turned into a god by Zeus.¹ He more than likely got his love for science from his father and this love for science promoted his future studies of nature, which were predominately biological. He also probably helped his father with his medical duties and learned to develop a keen eye for detail and a love for education and learning.

¹ Diogenes Laertius, *Lives of Eminent Philosophers*, trans. by R.D. Hicks (London: William Heinemann, 1925) V, 1.

Aristotle became a pupil of Plato when he was seventeen and remained so for twenty years.² During this time Plato would have taught Aristotle about the philosophers that came before. This line of studying promoted Aristotle to look at the world in a new way. He would eventually use many concepts from the philosophers he studied and develop his own ideas on those matters.

Aristotle had a curiosity about the world and a desire to understand as many aspects of it as possible, either through educating himself or investigating. This is why he was a pupil of Plato for so many years; he wanted to absorb as much information from Plato as he could. He also saw the importance of educating others; this is why he became a teacher. He would frequently express his opinion as to the importance of education:

ἔρωτηθεὶς τίνοι διαφέρουσιν οἱ πεπαιδευμένοι τῶν ἀπαιδευτῶν,
"ὅσῳ," εἶπεν, "οἱ ζῶντες τῶν τεθνεώτων." τὴν παιδείαν ἔλεγεν ἐν
μὲν ταῖς εὐτυχίαις εἶναι κόσμον, ἐν δὲ ταῖς ἀτυχίαις καταφυγὴν.
τῶν γονέων τοὺς παιδεύσαντας ἐντιμωτέρους εἶναι τῶν μόνον
γεννησάντων· τοὺς μὲν γὰρ τὸ ζῆν, τοὺς δὲ τὸ καλῶς ζῆν
παρασχέσθαι.³

Being asked how the educated differ from the uneducated, "As much," he said, "as the living from the dead." He said that education is a decoration in prosperity and a refuge in adversity. Those who educated children are to be honored more than those who merely gave birth; for the one life is furnished, the other a good life is furnished.

² Diogenes Laertius, *Lives of Eminent Philosophers*, V, 9.

³ Diogenes Laertius, *Lives of Eminent Philosophers*, V, 19.

His love for education is probably why he left so many of his ideas behind in writing. This way, others could learn and expand on his ideas.

There is a belief that Aristotle was the first to come up with the model of spontaneous generation. However, he probably was inspired by ideas from philosophers before him. Anaximander of Miletus lived from 611 to 547 B.C.E.⁴ He was probably the first philosopher to suggest a form of spontaneous generation. None of Anaximander's writings have survived but his ideas have been passed down through other philosophers' writings.⁵

Ἀναξίμανδρας ἐν ὑγρῷ γεννηθῆναι τὰ πρῶτα ζῶα φλοιοῖς
περιεχόμενα ἀκανθώδεσι, προβαίνουσης δὲ τῆς ἡλικίας
ἀποβαίνειν ἐπὶ τὸ ξηρότερον καὶ περιορηγνυμένου τοῦ φλοιοῦ
ἐπ' ὀλίγον χρόνον μεταβιῶναι.⁶

Anaximander said that the first creatures were born in moisture enclosed in thorny barks, and that as their age increased they came forth on to the drier part and when the bark had broken off they lived for a short time. This idea of spontaneous generation concerns more the beginning of earth, when creatures were first generated. It probably stemmed more from mythology than scientific thought. Censorinus wrote: "Anaximander of Miletus conceived that there arose from heated water and earth either fish or creatures very like fish."⁷ This gives the sense that the combination of heat, water, and earth, when united in a certain way, can

⁴ Diogenes Laertius, *Lives of Eminent Philosophers*, II, 1-2.

⁵ Osborn, Henry Fairfield, *From the Greeks to Darwin* (London: Macmillan and Co., 1913) 33, 35.

⁶ Aetius, "Book V," *The Presocratic Philosophers*, Kirk, G.S., J.E. Raven (Cambridge: Cambridge University press, 1971) 141.

⁷ Censorinus, *De Die Natale*, trans. by William Maude (New York: The Cambridge Encyclopedia Co., 1900) 7-8.

spontaneously generate particular creatures. Both passages explain that the ultimate beginning of various life forms was by means of spontaneous generation.

Anaximenes, a pupil of Anaximander, also wrote about events that seemed to be similar to the phenomenon of spontaneous generation. Anaximenes was also from Miletus and was born in 588 and died in 524 B.C.E.⁸ He introduced the idea that the generation of creatures and objects could come into being from air through the movement and changing of air in an abiogenetic fashion.

Ἄναξιμένης...ἀέρα ἄπειρον ἔφη τὴν ἀρχὴν εἶναι, ἐξ οὗ τὰ
γινόμενα καὶ τὰ γεγονότα καὶ τὰ ἐσόμενα καὶ θεοὺς καὶ θεῖα
γίνεσθαι, τὰ δὲ λοιπὰ ἐκ τῶν τούτου ἀπογόνων. τὸ δὲ εἶδος τοῦ
ἀέρος τοιοῦτον· ὅταν μὲν ὀμαλώτατος ᾖ, ὄψει ἄδηλον,
δηλοῦσθαι δὲ τῷ ψυχρῷ καὶ τῷ θερμῷ καὶ τῷ νοτερῷ καὶ τῷ
κινουμένῳ. κινεῖσθαι δὲ αἰεὶ· οὐ γὰρ μεταβάλλειν ὅσα
μεταβάλλει, εἰ μὴ κινεῖτο...ὥστε τὰ κυριώτατα τῆς γενέσεως
ἐναντία εἶναι, θερμόν τε καὶ ψυχρόν.⁹

Anaximenes...said that the infinite air was the principle, from which the things that are becoming and that are and that shall be and gods and things divine come into being, and the rest from its products. The form of air is of this kind: whenever it is most equable, it is invisible to sight, but is revealed by the cold and the hot and the damp and by movement. It is

⁸ Diogenes Laertius, *Lives of Eminent Philosophers*, II, 3.

⁹ Hippolytus, *Refutations to All Heresies*, ed. by Miroslav Marcovich (New York: W. De Gruyter, 1986) I, 7, I.

always moving: for things that change do not change unless there is movement... The result is that the most influential components of generation are opposites, hot and cold.

Air, principle to life, produces an environment necessary for beings to be spontaneously generated. This environment could be imagined as a damp mist, and through the heating and cooling of this mist, creatures are formed in a spontaneous manner.

Empedocles of Agrigentum, who lived from 484 till 424 B.C.E also believed in spontaneous generation.¹⁰ However, he thought that Nature went through a series of trials before producing animals. The creatures that were spontaneously generated went through a natural selection before any were able to survive.

ὅπου μὲν οὖν ἅπαντα συνέβη ὥσπερ κὰν εἰ ἔνεκά του ἐγίνετο,
ταῦτα μὲν ἐσώθη ἀπὸ τοῦ αὐτομάτου συστάντα ἐπιτηδείως·
ὅσα δὲ μὴ οὕτως, ἀπώλετο καὶ ἀπόλλυται, καθάπερ
Ἐμπεδοκλῆς λέγει τὰ βουγενῆ ἀνδρόπρωρα'.¹¹

Wherever then all the parts came about just as they would have been if they had come to be for an end, such things survived being organized spontaneously in a fitting way; whereas those which grew otherwise perished and continue to perish, as Empedocles says his “man-faced oxen” did.

These creatures are not only spontaneously generated from the earth, but also their limbs are spontaneously put together. The different mixture of limbs put together creates many

¹⁰ Diogenes Laertius, *Lives of eminent Philosophers*, VIII, 52.

¹¹ Aristotle, *Physics*. trans by W. D. Ross (Oxford: Clarendon Press, 1955) VIII, 198 b 29-34.

varied creatures. Some of these creatures survived, while others did not. These dissimilar mixes allowed for diverse generations to follow.

Ἐμπεδοκλῆς τὰς πρώτας γενέσεις τῶν ζώων καὶ φυτῶν
μηδαμῶς ὀλοκλήρους γενέσθαι, ἀσυμφυέσι δὲ τοῖς μορίοις
διεzeugμένας, τὰς δὲ δευτέρας συμφυομένων τῶν μερῶν
εἰδωλοφανεῖς, τὰς δὲ τρίτας τῶν ὀλοφυῶν, τὰς δὲ τετάρτας
οὐκέτι ἐκ τῶν ὁμοιομερῶν οἶον ἐκ γῆς καὶ ὕδατος, ἀλλὰ δι'
ἀλλήλων ἤδη.¹²

Empedocles held that the first generations of animals and plants were not formed complete, but consisted of separate limbs not joined together; the second arising from the joining of these limbs were like creatures in dreams, the third was of whole-natured forms, and the fourth arose no longer from the homeomerous substances such as earth and water, but by generation.

This passage explains the generation process, from spontaneously generated limbs to spontaneously generated creatures to creatures arising from other creatures. The creatures first were formed from limbs that were made spontaneously from earth and water. This explanation was probably seeped in mythology. Empedocles was possibly trying to create reasons for different mythological characters. The deformities, which these creatures were formed with, were reasons they no longer existed. The deformities prevented them from being able to survive in the world for too long.

¹² Aetius, "Book V," *The Presocratic Philosophers*, 336.

The training Aristotle received, both from his father and Plato, set him on a course to investigate many aspects of the world. He eventually delves into observations of nature and discovers that there are some creatures that form and their origins seem to be unexplainable. He proposes a theory that spontaneous generation did not just occur when life was first forming, but is currently occurring in certain creatures.

Aristotle's Spontaneous Generation

Over numerous centuries there have been different interpretations as to what Aristotle meant when he was referring to spontaneous generation. A modern biology textbook now only gives the general definition of spontaneous generation as the theory that living organisms can arise from nonliving matter.¹³ For centuries, students and scientists have misunderstood Aristotle's notion of spontaneous generation because of this generalization. It leads students to believe that any organism could potentially arise from nonliving matter. The only true way to discover the secrets of Aristotle's spontaneous generation theory is to view the world as Aristotle saw it. One way to do this is through an analysis of his texts.

What exactly is Aristotle's notion of spontaneous generation and what creatures does it concern? According to Aristotle, there are two main varieties of animals—the blooded and the bloodless. The blooded animals consist of a wide variety of land and sea

¹³ Bauman, Robert W. *Microbiology* (San Francisco: Benjamin Cummings, 2004) Appendix G-16.

creatures including birds, humans, fish, and eels. The bloodless consist of the Crustacea (lobster, crab), Cephalopods (octopus, cuttle-fish), Insects, Testacea (snail, oyster).¹⁴ Spontaneous generation is mainly concerned with the bloodless animals because some of them lack the ability to produce soul-heat (θερμότης ψυχῆς), which is a necessary component in generating offspring and is found in blooded animals. Soul-heat acts as a motive power that is produced in larger animals out of necessity. Larger animals require greater amounts of power to be able to move themselves and to be able to copulate. Since some bloodless animals, because of their small size, lack the soul-heat necessary to produce offspring, there must be some other place where soul-heat can be obtained.¹⁵ The general idea behind spontaneous generation is that there are certain life forms that seem to have unexplainable origins, since they are not generated from adults of the same species, but from rotten earth and residues.

τῶν δ' ἀναίμων τὰ μὲν ἔχει τὸ θῆλυ καὶ τὸ ἄρρεν, ὥστε τὰ
 ὁμογενῆ γεννᾶν, τὰ δὲ γεννᾶ μὲν, οὐ μέντοι τὰ γε ὁμογενῆ·
 τοιαῦτα δ' ἐστὶν ὅσα γίνεται μὴ ἐκ ζώων συνδυαζομένων, ἀλλ'
 ἐκ γῆς σηπομένης καὶ περιττωμάτων.¹⁶

But of the bloodless [animals] some have both female and male, so that they generated [identical] offspring, others also generate, yet not offspring; such are [creatures] which do not come into being from the coupling of animals, but, from rotten earth and residues.

¹⁴ Aristotle, *Generation of Animals*, ed. and trans. by A. L. Peck (Cambridge: Harvard University Press, 1943) I, 720 b 4-7.

¹⁵ Aristotle, *Generation of Animals*, II, 732 a 18-23.

¹⁶ Aristotle, *Generation of Animals*, I, 715 a 21-25.

These creatures that come from putrescent earth and residues are considered to have spontaneously generated from this matter, rather than being born or generated from a being of the same kind. If this residue comes from an animal, then the new animal generated is observed as something completely different from the animal releasing the residue. Many animals that arise inside a different kind of animal are arising from the residues of the producing animal's parts.¹⁷ These observations are only as good as the human eye. Unfortunately, the human eye cannot see the microscopic level. For someone who was living nineteen hundred years before the first microscope, one can only speculate that he interpreted these events as being spontaneous since the life forms do appear to develop spontaneously to the human eye.

Aristotle observed spontaneous generation to occur most often in the groups of bloodless creatures—the Insects and the Testacea. Insects can be produced in a variety of places, during different times throughout the year, and out of various substances. They can be produced from the dew on foliage.¹⁸ The time of year only affects the generation when there is a need for a certain climate. Therefore, spontaneous generation most often occurs in the spring for Insects. However it could also take place during winter, so long as there is a good amount of temperate weather with southerly winds. Insects can be generated from putrefying mud and dung, in either green or dry wood, in the hair or skin of animals, and other residues either expelled or still within the living animal.¹⁹ This variety of sources explains why there are so many different kinds of Insects that can be found mainly in the spring and summer in distinct areas.

¹⁷ Aristotle, *Historia Animalium II*, ed. and trans. by A. L. Peck (London: William Heinemann LTD, 1952) V, 539 a 24-25.

¹⁸ Aristotle, *Historia Animalium II*, V, 551 a 1-2.

¹⁹ Aristotle, *Historia Animalium II*, V, 551 a 2-8.

Often when spontaneous generation occurs in the Insect category, a larva or larva look-a-like is formed. A larva does not automatically mean that spontaneous generation has occurred, because Insects can generate larvae by means of copulation.²⁰ Larva are different from eggs in the fact that a larva is formed out of an entire being rather than some part of it like eggs.²¹ Aristotle gives the example of the butterfly which arises from the caterpillar. They seem to be two completely different creatures, one that looks like a worm and can only crawl around, the other having symmetric wings and able to fly. The caterpillar enters into a *chrysalis* stage which looks similar to a larva. During the caterpillar stage they would take nourishment in and emit residues but during the *chrysalis* stage neither of those events occurs. After a while, the covering bursts open and a butterfly flies out.²² The butterfly therefore appears to have been generated from the residues of the caterpillar. Since the butterfly generated from a completely different animal, then the process must have been via spontaneous generation, according to Aristotle.

Another group of animals that often come to life by spontaneous generation is the Testacea. One place where a Testacean could be found would be on the side of a boat where a frothy slime has putrefied.²³ The sea water and earth provide the means for an encasement where the creature can develop. Aristotle also tells of places where the area has become muddy because of lack of water and he has found “lagoon-oysters,” which are a kind of testaceous animal.²⁴ As an example, Aristotle tells of a naval squadron, which cast anchor off Rhodes and threw some earthenware pots into the sea. After a

²⁰ Aristotle, *Generation of Animals*, III, 758 b 7-9.

²¹ Aristotle, *Generation of Animals*, III, 758 b 10-15.

²² Aristotle, *Historia Animalium II*, V, 551 a 13-14, 18-20, 23-27.

²³ Aristotle, *Generation of Animals*, III, 763 a 27-29.

²⁴ Aristotle, *Generation of Animals*, III, 763 a 29-31.

while spent in the mud, oysters would be found inside the pots.²⁵ Also, to prove that oysters emit no generative substance, he told of people from Chios who transported live oysters from Pyrrha in Lesbos and deposited them into sea-straits where currents met. The oysters never increased in number, only in size.²⁶ Given the currents, no mud was able to settle and therefore the conditions were not sufficiently stable for spontaneous generation. There is a part of the oyster that appears to contain eggs. However, for Aristotle, the eggs do not contribute to the generations but merely provide nourishment as fat does for blooded animals.²⁷ If the currents were too strong then oysters probably would not be able to produce offspring: the currents would take away the eggs before they could be fertilized and deposited.

Even though most blooded animals are formed through copulation, there are some that are formed by spontaneous generation. For example, most fish are generated by eggs, but Aristotle believes that there are some that are formed by spontaneous generation.²⁸ Aristotle observed the occurrence of what he thought was spontaneous generation in ponds. He gave an example of a pond near Knidos that dried up at one time and all the mud was taken out (meaning it dried up to the point of being a solid surface rather than soggy). Once water began to collect in it with rainfall, tiny fish appeared. These fish were similar to a grey mullet and appeared to not come from copulation, but from spontaneous generation. Aristotle justified his findings by explaining that none of them had the means to copulate, meaning that they did not have either egg or milt (the

²⁵ Aristotle, *Generation of Animals*, III, 763 a 31-34.

²⁶ Aristotle, *Generation of Animals*, III, 763 b 1-5.

²⁷ Aristotle, *Generation of Animals*, III, 763 b 5-7.

²⁸ Aristotle, *History of Animals II*, VI, 569 a 10-12.

sperm-containing fluid of a male fish).²⁹ These fish, according to Aristotle, rise from one of two sources, from mud or from sand and from decayed matter on the surface of the sand.³⁰ Another example of a fish is the froth of the small fry that comes out of sandy ground. The fry is thought to be unable to grow or to propagate its own kind and when it dies off another takes its place (more than likely from the residues left behind).³¹ Also, these fish only get caught when the weather is warm. From this, Aristotle concludes that the warm weather is a necessity for their formation. These fish are formed in shaded and marshy places where the ground can be warmed.³² Again, this explains the necessity of a warm area for spontaneous generation to proceed.

Another type of blooded animal that is thought to come into being by means of spontaneous generation is an eel. Aristotle did some investigating into how they might propagate by cutting eels open. He never found evidence of passages for milt or for eggs or even milt and eggs themselves.³³ He found that in standing pools, after the water was drained off and the mud was dredged away, eels appear again after a fall of rain. In times of drought, eels do not appear in stagnant ponds, because Aristotle hypothesizes that their existence depends on rain-water.³⁴ He believes that the “earth’s guts” (γῆς κντρον), which take shape spontaneously in mud and wet soil is a component of spontaneous generation for eels.³⁵ The “earth’s guts,” also known as earthworms, have the nature of a larva and the eels are formed within them.³⁶ Eels have been seen emerging from these earthworms both in the sea and in rivers. They are most prevalent in the sea around

²⁹ Aristotle, *History of Animals II*, VI, 569 a 14-19.

³⁰ Aristotle, *History of Animals II*, VI, 569 a 27-29

³¹ Aristotle, *History of Animals II*, VI, 569 a 30-b 3.

³² Aristotle, *History of Animals II*, VI, 569 b 8-11.

³³ Aristotle, *History of Animals II*, VI, 570 a 4-6.

³⁴ Aristotle, *History of Animals II*, VI, 570 a 8-12.

³⁵ Aristotle, *History of Animals II*, VI, 570 a 15-18.

³⁶ Aristotle, *Generation of Animals*, III, 762 b 27-29.

seaweed and in the rivers and marshes near the edge because at water's edge the sun-heat has its chief power and produces putrefaction.³⁷ Again, warmth is a necessity in order for spontaneous generation to occur.

Spontaneous generation is not limited to animals; it can also occur in the plant kingdom. Aristotle describes the different ways plants form:

Ἔστι δὲ καὶ ἐπὶ τῶν φυτῶν τὸν αὐτὸν τρόπον· τὰ μὲν γὰρ ἐκ σπέρματος γίνονται, τὰ δ' ὡσπερ αὐτοματιζούσης τῆς φύσεως· γίνονται γὰρ ἢ τῆς γῆς σηπομένης ἢ μορίων τινῶν ἐν τοῖς φυτοῖς· ἓνια γὰρ αὐτὰ μὲν οὐ συνίσταται καθ' αὐτὰ χωρὶς, ἐν ἑτέροις δ' ἐγγίνονται δένδροισιν, οἷον ὁ ἰξός.³⁸

This mode of life is also among plants; for some are formed from seed, others just as if from a spontaneous activity of nature; for they are formed either from rotten earth or certain parts in plants; since some do not take shape separately on their own, but grow on other trees, such as mistletoe.

This shows that through his observations Aristotle finds that plants can exhibit the same spontaneous activity that animals do. For example, he describes a plant that is parasitic in nature. It will take over the growing space of other plants and destroy them. It would seem, to the unknowing eye, that the residues the plant left behind would have created the mistletoe, which appears to come out of nowhere other than from those residues. In fact, the mistletoe clings onto the other plant, blocking sunlight and using projections called haustoria to gain nutrients from vascular tissue of its host plant; this activity will

³⁷ Aristotle, *History of Animals II*, VI, 16.

³⁸ Aristotle, *Generation of Animals*, I, 715 b 26-30.

eventually kill the plant that the mistletoe clings onto.³⁹ From these projections, part of the plant starts to die and these parts will appear to be giving off residues, out of which the mistletoe grows.

Even if spontaneous generation appears to occur, what exactly is the cause of it or the cause of any life coming into being? Aristotle believes that it is a transaction between a proper amount of heating and cooling that provides the pathway to create any life form. This action is partly out of necessity and partly for a purpose. For instance, skin is on the surface because glutinous substances cannot evaporate like other parts of the animals' bodies inside.⁴⁰ The idea of heating and cooling can be seen as the harder substances of the animals' bodies were cooled more-so than the liquid parts or semi-hard parts. Also, this idea of heating and cooling could be more uniform where the whole body is either heated or cooled and the materials that make up each part determines how hard or soft they will become at a specific temperature. The latter idea seems more logical when reading along with Aristotle's text, because he describes the specific substance of skin and why it does not evaporate.

For most life (the blooded animals and some bloodless animals) the action of heating and cooling is provided by the semen from the male and the egg or container in which the offspring develops. However, those life forms that develop spontaneously must rely on a different source.

τοῖς δὲ αὐτομάτως γινομένοις ἢ τῆς ὥρας αἰτία κίνησις καὶ

³⁹ Campbell, Neil, Jane Reece, Lawrence Mitchell, *Biology*, 5th ed. (New York: Addison Wesley Logman, 1999) 726.

⁴⁰ Aristotle, *Generation of Animals*, II, 743 b 1-13.

θερμότης.⁴¹

With those [animals] that form spontaneously the cause is the motion and heat of the climate.

In the case of spontaneous generation, the parent does not provide the heating and cooling system as with other animals. The life form must rely on the climate to create this system. The typical climate for this system would be one that can generate soul-heat to provide for the heating and cooling. This is the reason there can only be specific places where spontaneous generation could occur.

Aristotle considers sea-water, rather than fresh water, as being a better environment for spontaneous generation for various reasons. Sea-water is fluid and much more substantial than fresh water. Also, Aristotle believes sea-water is hot by nature, where heated areas promote spontaneous generation. Also, it contains a quota of all parts necessary for spontaneous generation—fluid, πνεῦμα, and earth. The sea provides a place for both warmth and nourishment desired by many life forms.⁴² All of these qualities add up to present a perfect opportunity for spontaneous generation to occur.

Aristotle's observations are not the only stimulus for this concept. He pulls in his beliefs about all life to form his idea about how it is possible to have spontaneous generation occur.

Γίνεται δ' ἐν γῆ καὶ ἐν ὑγρῷ τὰ ζῶα καὶ τὰ φυτὰ διὰ τὸ ἐν γῆ μὲν ὕδωρ ὑπάρχειν, ἐν δ' ὕδατι πνεῦμα, ἐν δὲ τούτῳ παντὶ

⁴¹ Aristotle, *Generation of Animals*, II, 743 a 35-36.

⁴² Aristotle, *Generation of Animals*, III, 761 b 9-12.

θερμότητα ψυχικήν, ὥστε τρόπον τινὰ πάντα ψυχῆς εἶναι
πλήρη· διὸ συνίσταται ταχέως, ὅπότεν ἐμπεριληφθῆ.⁴³

Animals and plants are formed in the earth and in the water because in earth water is present, and in water life is present, and in all life soul-heat is present, so that in a way all things are full of soul; therefore [life forms] quickly take shape, when it has been enclosed.

All beings composed of earth and water contain the very essence of life—*πνεῦμα*. This must be present in order for life to be created. Since it is found in earth and water, then in certain situations earth and water can come together and become enclosed. From this enclosure, a life can be formed spontaneously. This earth-water concoction is formed by the heat of a specific season, and in the case of animals, the heat is caused by specific nourishment.⁴⁴

The actual being that is produced by spontaneous generation is determined by the envelope that encloses the soul-heat, which contains soul. The creation and type of envelope is determined by where the process takes place and the physical substance which is enclosed.⁴⁵ Aristotle gives an example of a Testacean that is formed out of an earthy sea substance (possibly the sand from the Mediterranean) that hardens and congeals in the same way that bones do (indicating the outer shell of the oyster). The physical substance within the outer casing contains the life form that has become

⁴³ Aristotle, *Generation of Animals*, III, 762 a 19-23.

⁴⁴ Aristotle, *Generation of Animals*, III, 762 b 13-16.

⁴⁵ Aristotle, *Generation of Animals*, III, 762 a 26-28.

enclosed.⁴⁶ What being is formed is dependent on the physical substances enclosed in the envelope and the type of envelope.

Aristotle's spontaneous generation theory cannot be applied to all creatures because it can only occur under specific circumstances of climate, place, and substances able to be used. If these three requirements do not match up, then spontaneous generation will not occur. Also, spontaneous generation mostly occurs among the bloodless animals and plants because they are likely to have less soul-heat, which enables them to produce offspring. Although, among the blooded animals, there are some that do not contain soul-heat and are formed by spontaneous generation. Aristotle only had the use of his own eyes. If the microscope had existed for Aristotle to use, this theory may have been hypothesized differently.

Effects of Controlled Experimentation and Microbiology on the Theory of Spontaneous Generation

Aristotle's theory of spontaneous generation maintained its hold on the scientific community up until the seventeenth century. Before this time, in many cases what was seen through observation was taken as truth without thorough investigations. Many scientists of this century sought the truth through observations and experiments rather than just observations. Also, the introduction to the science of microbiology opened a new aspect of spontaneous generation that could be argued about. The new way of

⁴⁶ Aristotle, *Generation of Animals*, III, 762 a 29-33.

experimenting through controlled experiments and the introduction of microbiology led to divisions in the scientific community and created some skepticism towards the theory of spontaneous generation.

The first distinguished scientist that did an experiment to demolish the idea of spontaneous generation was Francesco Redi, a Jesuit-trained doctor. He published some studies in 1668 that were some of the first to apply the scientific method to experimentation. His motivation for conducting these experiments against spontaneous generation was because of his religious background.

I shall express my belief that the Earth, after having brought forth the first plants and animals at the beginning by order of the Supreme and Omnipotent Creator, has never since produced any kinds of plants or animals, either perfect or imperfect; and everything which we know in past or present times that she has produced, came solely from the true seeds of the plants and animals themselves.⁴⁷

He thought that spontaneous generation was not possible because it was written in the *Bible* that only God could create new life. If spontaneous generation were true then it would be going against God's word and could possibly negate other ideas in the *Bible*.

Worms (maggots) are one such creature that appear to be produced in dead bodies and decayed plants. Redi thought that these worms were generated by insemination and the putrefied matter served as a nest to deposit eggs and provide nourishment.⁴⁸ Redi, first, made observations of dead snakes in an open box, watching them decay. Within three days the snakes were covered with worms. On the twentieth day the worms took an

⁴⁷ Redi, Francesco, *Experiments on the Generation of Insects*, ed. and trans. by Mab Bigelow (Chicago: The Open Court Publishing, 1909) 26-27.

⁴⁸ Redi, Francesco, *Experiments on the Generation of Insects*, 27.

egg shape and within eight more days the egg-like container brought forth flies.⁴⁹ He repeated the experiment using different types of meat and all the time he saw flies swarming around the meat, making deposits.⁵⁰

According to Redi, he was not the first to notice the flies' presence around meat and the consequences that followed. Hunters and butchers covered their meat with white cloths during the summer to protect them from filth. This prevented flies from contaminating the meat with their eggs.⁵¹ Also, Redi points out that there are observations made about flies trying to infest Patrocles's body in the nineteenth book of the *Iliad*.

ἀλλὰ μάλ' αἰνῶς δεῖδω μή μοι τόφρα Μενoitίου ἄλκιμον υἱὸν
μυῖαι καδδῦσαι κατὰ χαλκοτύπους ὠτειλὰς εὐλὰς ἐγγείνωνται,
ἀεικίσσωσι δέ νεκρὸν-ἐκ δ' αἰὼν πέφαται-κατὰ δὲ χροά πάντα
σαπήνη.⁵²

Yet I am most horribly afraid that meantime flies will enter the wounds of the valiant son of Menoetius (Patrocles) inflicted with brazen arms and breed maggots therein, and will dishonor his corpse—and the life will be slain out of him—and all his flesh will rot.

Also, his Academy's compilers of the dictionary noted that the deposits dropped by flies on meat eventually became worms.⁵³

⁴⁹ Redi, Francesco, *Experiments on the Generation of Insects*, 28-29.

⁵⁰ Redi, Francesco, *Experiments on the Generation of Insects*, 32-33.

⁵¹ Redi, Francesco, *Experiments on the Generation of Insects*, 33.

⁵² Homer, *Iliad*, trans. by A. T. Murray (Cambridge: Harvard University Press, 1925) 19.23-27.

⁵³ Redi, Francesco, *Experiments on the Generation of Insects*, 33.

Redi decided to conduct an experiment using the idea of butchers and hunters. His experiment was to see if, by covering meat so that flies could not get to it, no worms would develop. If this happened, it would show a correlation between the flies landing on meat and worms developing. The experiment consisted of two sets of four large, wide-mouthed flasks with a snake, fish, eels and a slice of young veal. One set of four flasks was sealed with paper and the other was left open (as the control group). The meat and fish became wormy in the open vessels with flies coming and going as they pleased but the closed flasks never were inhabited by worms. The things in the flask had become putrid and stinking; the fish, with an exception to their bones, had all been dissolved into a thick, turbid fluid.⁵⁴ It seemed that it was a perfect environment for spontaneous generation to occur, yet nothing happened. He repeated the experiment with various different vessels and coverings, but always obtained the same result, no worms in the covered jars. To make sure of his findings, he used a fine Naples veil as the covering because it would allow air to flow into and out of the container. Again, no worms were found in the jar. Redi's conclusion from these experiments is that the worms that appeared on meat were deposited in eggs by flies rather than being spontaneously generated.⁵⁵

⁵⁴ Redi, Francesco, *Experiments on the Generation of Insects*, 33.

⁵⁵ Redi, Francesco, *Experiments on the Generation of Insects*, 34.



Figure 1: Depiction of Redi's experiment: when the flask remained unsealed maggots covered the meat within a few days. When the flask was sealed no maggots appeared on the meat. When the flask was covered with gauze, maggots appeared on the gauze but not on the meat.⁵⁶

This experiment allowed for a new insight on experimentation and showed that what appears to be true through one method is not always the truth. Redi got much prestige with this experiment and changed many minds in the scientific community about whether or not spontaneous generation can happen. Redi conducted experiments on various different insects including scorpions, bees and wasps, but no other experiment gained more esteem than the one concerning the appearance of maggots.

Although Redi's experiments may have added strength to the idea that macroscopic animals could not spontaneously generate, the world was then introduced to a new creature that could only be seen through the microscope. In the mid 1600s, Anthony van Leeuwenhoek made simple microscopes that consisted of a single lens. He was not the first to create microscopes, but in 1673 he was the first to discover the

⁵⁶ Bauman, W. Robert, *Microbiology*, 8.

microbial world. He used his instruments to make observations of these unknown creatures, which he called “little animals”.⁵⁷



Figure 2: Leeuwenhoek’s microscope. A simple device that contains a magnifying glass with screws for manipulating the specimen. The lens is convex on both sides and is about the size of a pinhead. The object being viewed was mounted on a specimen holder or inside a glass tube, which was mounted on the specimen holder.⁵⁸

Leeuwenhoek’s discovery sparked a new way for spontaneous generation to respawn after the findings of Francesco Redi. The naturalists (advocates for spontaneous generation) now had an argument that, although larger animals could not spontaneously generate, these new microscopic creatures must be formed by means of spontaneous generation. So the discovery of microbiology allowed the theory of Aristotle that concerned macro organisms to be set aside, and instead be transformed into a new theory concerning spontaneous generation on the microscopic level.

John Turberville Needham was a strong advocate for microbial spontaneous generation. He was born in London in 1713 and became an English Catholic priest in 1738.⁵⁹ Although his religious background should create reasons for him not to believe

⁵⁷ Willis, Christopher, Jeffrey Bada, *The Spark of Life: Darwin and the Primeval Soup* (Cambridge: Perseus Publishing, 2000) 6.

⁵⁸ Bauman, W. Robert, *Microbiology*, 2.

⁵⁹ Mazzolini, Renato G., Shirley A. Roe, *Science Against the Unbelievers: the Correspondence of Bonnet and Needham 1760-1780* (Oxford: The Voltaire Foundation, 1896) xvii.

in spontaneous generation, he did not see “why there should not be as much reason, if we take the wisdom of the Almighty, as far as we can possibly trace, our standard in this particular, in asserting that the foetus is generated from a lifeless point of matter, as in affirming that it proceeds from an animalcule?”⁶⁰ Needham did not see the difference, concerning microbials, in something that forms from a lifeless piece of matter or an Animalcule. He believes that when it concerns life, God is the creator no matter where it comes from or how it is formed.

Needham’s experiment consisted of mutton-gravy that was hot from a fire and then placed into a phial. This was heated as a sterilization step to ensure to others that there were no animalcules already in the gravy. The phial was also heated in ashes to sterilize it. The phial was then closed with a cork. The exclusion of exterior air was to prove that the organisms that formed were not from insects or eggs floating in the atmosphere. The phials were left outside to warm in the sun. After a short time he opened the phials and observed a drop of the mutton-gravy under the microscope. He found that the drop swarmed with life.⁶¹ He took these findings to be evidence of microbial spontaneous generation.

Let it suffice for the present to take notice, that the phials, closed or not closed, the water previously boiled, or not boiled, the infusions permitted to teem, and then placed upon hot ashes to destroy their productions, or proceedings in the vegetation without intermission, appeared to be so

⁶⁰ Needham, John Turberville, *An Account of Some New Microscopical Discoveries* (London, 1745) 83.

⁶¹ Needham, John Turberville, “A Summary of Some Late Observations on the Generation, Composition, and Decomposition of Animal and Vegetable Substances”, *Philosophical Transactions of the Royal Society of London*, Vol. 45, no. 490 (London, 1748) 628-630.

nearly the same, that, after a little time, I neglected every precaution of this kind, as plainly unnecessary.⁶²

He states the exact mistake he made, in that he neglected every precaution. He may have thought it unnecessary to take caution in his later experiments but in his very first one he forgot about one source of potential contamination: the cork he used to stopper the phial. He did not mention sterilizing this and probably picked it up off the counter where there are microbials. The cork probably had microbials and contaminated the experiment.

Needham also took this experiment to prove that “there is a vegetative Force in every microscopical point of matter, and every visible Filament of which the whole animal or vegetable texture consists: and probably this Force extends much farther.”⁶³ He takes this to mean that “every animal or vegetable substance advances as fast as it can in its Resolution to return by a slow Descent to one common Principle, the Source of all, a kind of universal Semen; whence its Atoms may return again, and ascent to a new Life.”⁶⁴ These proclamations seem to be creating a religion around rebirth, which has spontaneous generation as its central dogma.

Lazzaro Spallanzani first did a refutation experiment of Needham’s experiment in 1765. He was an Italian Abbot and a biologist who believed that Needham had not heated the phials sufficiently so that there were still eggs that were able to form into creatures. He believes that in order to have no creatures born, the air inside the closed

⁶² Needham, John Turberville, “A Summary of Some Late Observations on the Generation, Composition, and Decomposition of Animal and Vegetable Substances,” 630.

⁶³ Needham, John Turberville, “A Summary of Some Late Observations on the Generation, Composition, and Decomposition of Animal and Vegetable Substances,” 616.

⁶⁴ Needham, John Turberville, “A Summary of Some Late Observations on the Generation, Composition, and Decomposition of Animal and Vegetable Substances,” 617.

phial must be strongly heated while the infusions are inside.⁶⁵ There was a necessity to sterilize everything properly and an appropriate way to do this was by heat. He took four flasks and filled them with infusions. The first flask he heated for an hour and then sealed the flask by melting the mouth shut. Nothing grew in this flask. The second flask he heated for a few minutes and then sealed the flask by melting the mouth shut. This flask eventually got microbial growth. The third flask he heated for an hour and then sealed it with a cork. This flask also grew bacteria. For Spallanzani, this proved the reasons for bacterial growth in Needham's experiment. Needham did not allow the infusions to boil long enough to kill the microbials. Also, a cork does not completely seal the flask so that air was able to get around the edge and carry microorganisms with it.⁶⁶

Needham, four years later, had a response to Spallanzani's findings and published them as notes in Spallanzani's book. Needham explained how Spallanzani got results of phials without any life after heating them. He said that the heat had caused the infusions to become sterile with the heat destroying the "vegetative Force" in the matter and the "elasticity of air".⁶⁷

After the new publication, Spallanzani went into a series of experiments to prove the mythology of a "vegetative Force" in matter and "elasticity of air". The first part investigated was "whether according to a new theory of generation animalcula are produced by a vegetative power in matter."⁶⁸ He boiled seven different sets of seed infusions consisting of kidney beans, vetch, buckwheat, barley, maize, marrow, and

⁶⁵ Spallanzani, Lazzaro, *Nouvelles recherches sur les decouverts microscopiques et la generation des corps organizes* (Paris, 1769) 134.

⁶⁶ Spallanzani, Lazzaro, *Nouvelles recherches sur les decouverts microscopiques et la generation des corps organizes*, 134-135.

⁶⁷ Spallanzani, Lazzaro, *Nouvelles recherches sur les decouverts microscopiques et la generation des corps organizes*, 134.

⁶⁸ Spallanzani, Lazzaro, *Tracts on the Natural History of Animals and Vegetables*, trans. by J.G. Dalyell (Edinburgh, 1803) 1.

beets. Each kind was placed in four different vials and sealed loosely with a cork. The first was boiled for a half-hour, the second for an hour, the third for an hour and half, and the last for two hours.⁶⁹ If boiling does destroy the “vegetative force”, then the results would show those boiled for longer would contain fewer organisms than those boiled for less amount of time. This did not happen with Spallanzani’s experiments. Instead, they had about the same amount of organisms in all the containers. In some cases the infusions boiled longer contained more organisms.⁷⁰ Spallanzani concluded “that vegetable seeds never fail to produce animalcula, though exposed to any degree of heat....that the *vegetative power* is nothing but a work of imagination.”⁷¹

The other criticism Spallanzani had to rectify was the idea that heating a hermetically sealed container diminished the “elasticity of air.” For this experiment, Spallanzani took his vessels containing infusions and inserted capillary tubes. These tubes were able to instantaneously seal the vessels so that the internal air could not alter.⁷² After this, he boiled each set of infusions at four different times—half a minute, one minute, one minute and a half, and two minutes. He found that even at a half minute the larger microbials were prevented from occurring. Some of the smaller animalcules took up to 45 minutes to kill. He concluded that smaller infusorians (microbials) could resist heat of boiling.⁷³ However, he found out upon breaking the seal that a faint hissing noise could be heard. From this he had to suppose that the “heat had truly injured the elasticity of the internal air.”⁷⁴

⁶⁹ Spallanzani, Lazzaro, *Tracts on the Natural History of Animals and Vegetables*, 5-6.

⁷⁰ Spallanzani, Lazzaro, *Tracts on the Natural History of Animals and Vegetables*, 9.

⁷¹ Spallanzani, Lazzaro, *Tracts on the Natural History of Animals and Vegetables*, 13.

⁷² Spallanzani, Lazzaro, *Tracts on the Natural History of Animals and Vegetables*, 15.

⁷³ Spallanzani, Lazzaro, *Tracts on the Natural History of Animals and Vegetables*, 15-16.

⁷⁴ Spallanzani, Lazzaro, *Tracts on the Natural History of Animals and Vegetables*, 16.

Although Spallanzani did not prove that heating a sealed container does not affect the “elasticity of air”, he did create a doubt in many scientific thinkers about Needham’s “vegetative Force” theory. This was the first step towards scrapping the myth about spontaneous generation concerning microbials.

By the time Louis Pasteur got into the debate about spontaneous generation in the 1800s, most of the scientific world had given up on the macroscopic aspect of spontaneous generation; it was now primarily concerned with microbials. Louis Pasteur was already a well-known scientist for his studies in crystallography and fermentation. From his studies in fermentation and theory on germs he thought that he needed to investigate spontaneous generation to see if there were preexisting germs that caused the formation of microbials.⁷⁵

The philosophical, scientific, and religious debate about spontaneous generation continued without any real resolve until Louis Pasteur conducted his experiments concerning the matter.

Religion, philosophy, atheism, materialism, and spiritualism have nothing to say here. I might also add: As a scientist, I needn't worry about them. The present question is a matter of fact. I address it without prejudice, as ready to declare in favor of spontaneous generations, should experience attest to their existence, as I am now persuaded that those who affirm them have their eyes bound.⁷⁶

⁷⁵ Pasteur, Louis “Memoire sur les corpuscles organizes qui existent dans l’atmosphere: Examen de la doctrine des generations spontanees,” *Oeuvres de Pasteur.*, vol. 2 (Paris: Masson et C^{ie}, 1922) 3.

⁷⁶ Pasteur, Louis, *On Spontaneous Generation*, Address delivered by Louis Pasteur at the “Sorbonne Scientific Soiree” on April 7, 1864.

He went into his experiments as a scientist wanting to find the truth. It just happens that his experiments suggested that spontaneous generation was impossible.

One experiment, in 1860, involved his belief that “there exists in air a more or less mysterious principle, gas fluid, ozone, etc., having the property of arousing life in infusions.”⁷⁷ This theory seems to go back to the ancient Greeks with Anaximenes in his belief that air contains the principle of life, but Pasteur believed that this principle of life was a germ. He boiled a solution of sugar yeast for two minutes, filled the flask with calcinated air, and then sealed the neck of the flask with a flame. He let these contents stand for 18 months and they were still clear.⁷⁸ He then attached this sterile sugar, yeast, and water flask to tubes where he placed gun-cotton charged with atmospheric particles. He would then periodically break the seal and allow gun-cotton to slide in and then reseal the flask with a flame. Growth appeared after 24 to 48 hours in every case. Also, to show that the organism did not arise spontaneously from the gun-cotton, Pasteur substituted dust-free asbestos for the gun-cotton.⁷⁹ These results were that the solution remained clear. The conclusion was that it was the dust particles that caused the microbials to arise.⁸⁰

⁷⁷ Pasteur, Louis “Memoire sur les corpuscles organizes qui existent dans l’atmosphere: Examen de la doctrine des generations spontanees,” 274.

⁷⁸ Pasteur, Louis “Memoire sur les corpuscles organizes qui existent dans l’atmosphere: Examen de la doctrine des generations spontanees,” 235.

⁷⁹ Pasteur, Louis, “Memoire sur les corpuscles organizes qui existent dans l’atmosphere: Examen de la doctrine des generations spontanees,” 239-244.

⁸⁰ Pasteur, Louis, “Memoire sur les corpuscles organizes qui existent dans l’atmosphere: Examen de la doctrine des generations spontanees,” 246.

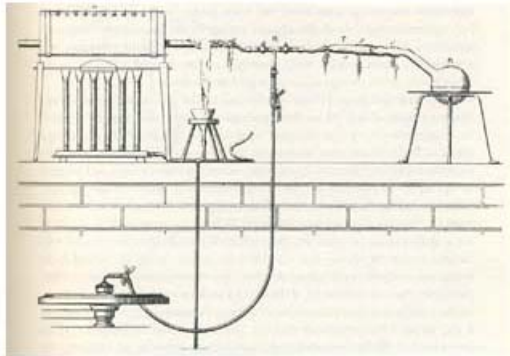


Figure 3: Pasteur apparatus for collecting solid particles from atmospheric air and then introducing them into a previously sterile flask.⁸¹

One of Pasteur's adversaries was Felix Pouchet, the Director of the Rouen Museum of Natural History and an active member of the Academy of Sciences, who in 1858 told the Academy that he had succeeded in producing experiments which demonstrated, beyond the shadow of a doubt, the existence of microscopic creatures that entered the world without germs, and thus without parents resembling themselves. Pouchet believed that air neither is, nor could be, the bearer of the germs for these primitive organisms.⁸² Pasteur repeats the experiment during his address to prove that microorganisms do not exist in air but spontaneously generate. A liter is filled with boiling water, sealed with care and inverted over mercury. After the water cools, the flask is uncorked below the mercury and pure oxygen is introduced. Then hay infusions are introduced below the surface of mercury. These hay infusions were contained in a vial where it was sealed with emery and heated in an oven for 30 minutes. The result is that

⁸¹ Pasteur, Louis, "Memoire sur les corpuscles organizes qui existent dans l'atmosphere: Examen de la doctrine des generations spontanees," 239.

⁸² Pasteur, Louis, *On Spontaneous Generation*, Address delivered by Louis Pasteur at the "Sorbonne Scientific Soiree."

after ten days there is a fully developed mold. The conclusion was that the atmosphere did not contain microbials or germs, but rather they are formed spontaneously.⁸³

Pasteur believes that this experiment must have a contaminant. Pouchet's experiment may have taken all precautions to avoid microbial contamination but one part was not thought to contain microbes. The oxygen used was pure since Pouchet had extracted it from a chemical compound. The water used may have been contaminated when exposed to the air, but the water was boiling and that would have killed the germs. The hay also was heated so that all germs were eliminated. The one item that was taken for granted was the mercury, no precautionary steps were taken to purify the mercury and therefore it was probably contaminated.⁸⁴

To prove the mercury was contaminated, Pasteur turned the lights out with only a dim light shining on the vat of mercury. This was to provide an effect of seeing dust particles much like those seen in a sun ray coming through blinds. He then put a glass rod down into the vat of mercury. The dust particles on top of the mercury go into the vat as the rod is pushed down. Mercury will always become contaminated when something pushes down into it; hence Pouchet's experiment was contaminated with germs.⁸⁵

The experiment that was most influential in changing many minds about spontaneous generation was inspired by the efforts of Lazzaro Spallanzani. Pasteur took the same idea of boiling organic infusions in flasks but instead of closing them, he created a swan-like neck that allowed air in and out. The infusions that were boiled did

⁸³ Pasteur, Louis, *On Spontaneous Generation*, Address delivered by Louis Pasteur at the "Sorbonne Scientific Soiree."

⁸⁴ Pasteur, Louis, *On Spontaneous Generation*, Address delivered by Louis Pasteur at the "Sorbonne Scientific Soiree."

⁸⁵ Pasteur, Louis, *On Spontaneous Generation*, Address delivered by Louis Pasteur at the "Sorbonne Scientific Soiree."

not ferment while the ones that were not boiled did. As a control, he used regular flasks that were not sealed and let them boil. These flasks became contaminated with microbials that came in by the air. From this, Pasteur concluded that the necks prevented the atmospheric particles to go into the infusion, preventing contamination.⁸⁶ The swan necks allowed air to flow in and out which was one of Needham's complaints of the Spallanzani experiment. The "elasticity of the air" was not disturbed even though the infusions were boiled. Spallanzani had already established doubt in the "vegetative Force" idea by showing that the straight-necked open flasks had contained microbials after boiling. The microbials, in Pasteur's experiment, carried in by the air probably were settled in the moist curved neck of the flasks. This moist area would have been caused by the boiling of the infusions. If the flask was rapidly shaken and allowed the infusions to come into contact with the neck (hence to come into contact with dust), within a few days the infusions would become cloudy indicating presence of animalcules and mold.⁸⁷ This shows that the dust containing microbials would get stuck in the moisture of the curved part of the neck.

⁸⁶ Pasteur, Louis, *On Spontaneous Generation*, Address delivered by Louis Pasteur at the "Sorbonne Scientific Soiree."

⁸⁷ Pasteur, Louis, *On Spontaneous Generation*, Address delivered by Louis Pasteur at the "Sorbonne Scientific Soiree."

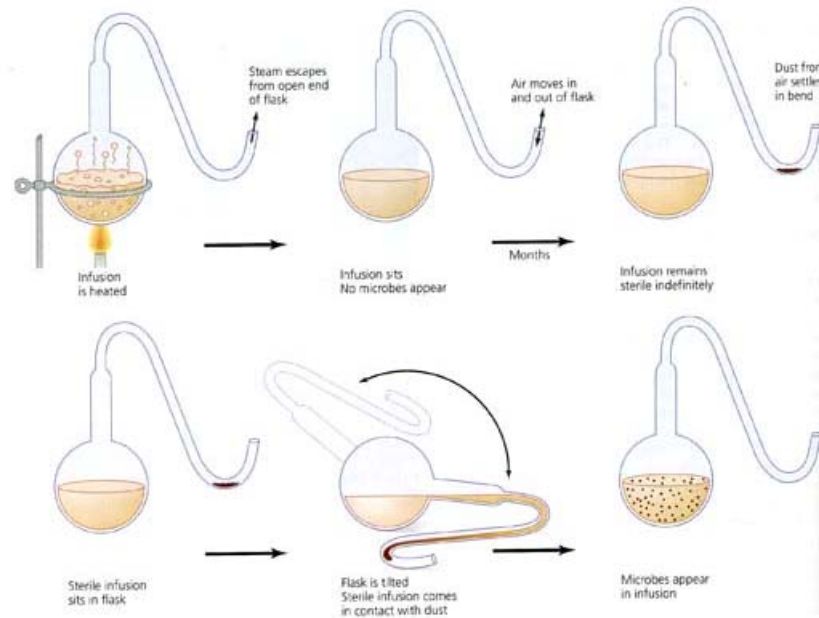


Figure 4: Pasteur’s experiment with the “swan-necked flasks.” As long as the flask remained upright, no microbial growth appeared in the infusion. When the flask was tilted so that some dust from the bend in the neck was carried back into the flask, the infusion became cloudy with microbes.⁸⁸

This experiment showed that so long as infusions were isolated from air containing dust particles and therefore containing microbials, it would remain sterile. As Louis Pasteur puts it:

“It remains thus because I have deprived it, and continue to deprive it, of the one thing it is not given to man to produce; I have deprived it of air-borne germs, or of life itself--for life is the germ, and the germ is life. The

⁸⁸ Bauman, W. Robert, *Microbiology*, 10.

doctrine of spontaneous generation will never recover from the mortal blow inflicted by this experiment.”⁸⁹

The debate about spontaneous generation may have come to a halt with Louis Pasteur’s findings, but what did the experiments really prove? His experiments showed that there are germs in the atmosphere that could cause microbial formation. He showed the scientific world that, even though something appears to be, that does not necessarily mean that is truth. Although microbes appear to come out of nowhere, there are some already there that generate others. Going into experimentation without any preferences as to the outcome will always grant a better outcome because fewer mistakes will be made on account of getting the result you want.

Conclusion

Aristotle’s theory may not have any precedence in the scientific community anymore, but some of its remnants still are around in modern science. The identification of microbials brought to the scientific world a new form of being, new questions, and new answers. Although the theory of spontaneous generation cannot occur under the circumstances Aristotle believed was possible, either for Aristotle’s macroscopic creatures or the seventeenth century’s microscopic creatures, there is a new theory that seems to be generated from spontaneous generation. The modern day evolution theory has life coming from a primordial soup that set in the right conditions, life can be created from certain molecules.⁹⁰ Aristotle’s own theory needed specific environmental conditions for spontaneous generation to be able to happen. So, in a way, Aristotle’s

⁸⁹ Pasteur, Louis, *On Spontaneous Generation*, Address delivered by Louis Pasteur at the “Sorbonne Scientific Soiree.”

⁹⁰ For more information on the modern day evolution theory as related to spontaneous generation go to *The Spark of Life: Darwin and the Primeval Soup* by Christopher Will and Jeffrey Bada.

theory was revoked and then rebuilt on more specific conditions concerning microscopic molecules.

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