

# From miasmas to germs: a historical approach to theories of infectious disease transmission

***Dai miasmi ai germi: un approccio storiografico alle teorie della trasmissione delle malattie infettive***

Marianna Karamanou<sup>1</sup>, George Panayiotakopoulos<sup>2</sup>,  
Gregory Tsoucalas<sup>1</sup>, Antonis A. Kousoulis<sup>1</sup>, George Androutsos<sup>1</sup>

<sup>1</sup>History of Medicine Department, Medical School, University of Athens, Athens, Greece;

<sup>2</sup>Clinical Pharmacology, Medical School, University of Patras, Patras, Greece

## ■ INTRODUCTION

Throughout centuries philosophers and scientists tried to explain the way of infectious diseases transmission. Witchcraft, demons, gods, comets, earthquakes were the first unproved theories, followed by tangible scientific ones such as miasma's theory, contagious theory, spontaneous generation theory and germ theory till the evolution of microbiology in mid 19<sup>th</sup> century.

### *Early transmission theories and the miasma theory*

Primitive ideas about contagiousness dealt with the general notion of transmission through contact. Epidemics were probably rare in small primitive tribes but they became terrifying events once population density increased enough to produce and sustain them. At that time people's ignorance led to magical or religious explanations of disease, sent by the gods as punishment for their sins [1]. Among many primitive tribes, as well as in the highly developed sacerdotal practices of ancient cultures, we find suggestive fragments of infectious diseases transmission embedded in a matrix of religion [2, 3]. Characteristically, in Ancient Persia we see an emphasis on demonology. The disease is caused by evil spirits and must be controlled by exorcism. The cult of Nergal, a demon portrayed in hymns and myths as a god of war, fever and pestilence, was of a great impor-

tance [4]. In Ancient Rome fever had three temples, in Palatine Hill, in Vicus Longus and in Sacra Via and was supplicated as the Goddess Febris who protected people from fever and malaria [5].

In 6<sup>th</sup> century BC, the pre-Socratic philosophers Pythagoras, Alcmaeon, and Empedocles inaugurated the period in science where the environment was understood to play a vital role in health and disease. A century later, *Airs, waters and places* of the Hippocratic texts, correlated a variety of symptoms and diseases with geographical and meteorological conditions, for example malaria, catarrh and diarrhea were believed to be due to the effect of seasonal changes on stagnant water or marshy places [6]. Such concepts survived and in time consolidated in the belief that a pathological state of the atmosphere is associated with infectious diseases and this line of thinking developed further into the miasma theory of contagion [7]. Air became contaminated with "miasmas", poisonous vapors produced by putrefying organic matter and a person could become infected when miasmas invaded the body and disturbed its vital functions.

In his manuscript about hygiene-based regulation for selecting building sites, entitled *De architectura*, the Roman architect Marcus Vitruvius Pollio (70 BC-15 BC) revokes the miasma theory and warned against swampy places: "For when the morning breezes blow toward the town at sunrise, if they bring with them

mist from marshes and, mingled with the mist, the poisonous breath of creatures of the marshes to be wafted into the bodies of the inhabitants, they will make the site unhealthy" [8]. Galen (130- c. 201 D) the most famous physician of the Roman period emphasizes also the miasma theory as he recognizes plague, tuberculosis and skin diseases as contagious [9].

As we pass from the classical to the early centuries of the Christian era, we find the contagiousness of leprosy playing a major role in the basis of the Old Testament. In *Leviticus Book*, a sanitary code almost free from any elements of supernaturalism, we notice a system for controlling leprosy involving differential diagnosis, isolation, quarantine and disinfection that remains the most brilliant application of rational epidemiology of ancient times. In the Byzantine period the spread of leprosy is also mentioned in the writings of Aretaeus of Cappadocia (1<sup>st</sup> century AD). He states that the breath is the vehicle for disease transmission. In the 6<sup>th</sup> century AD the bubonic plague epidemic also named "Justinian Plague" furnished new information's to the concept of contagion [10]. The historian Evagrius Scholasticus (537-594) described the plague and considered it transmitted by contact, visiting infected houses or even by interpersonal relationship in the market place [2].

#### *The contagious theory of Girolamo Fracastoro*

In the medieval period epidemic disease was associated in people's mind with comets, eclipses, earthquakes or major astrological disturbances that charged the air with poisonous vapors known as "miasmas". The miasma theory was again the dominant theory of contagion because of people's observation that the epidemics and mainly the plague tended to occur during the hot summer months where the air in the cities was humid and filled with the odours of garbage, decomposing animals and human waste.

During the 16<sup>th</sup> century, Girolamo Fracastoro (1478-1553) poet, physician and mathematician attempted to analyze the concept of contagion and infection. In his major clinical work *On Contagion, Contagious Diseases and Their Cure*, published in 1546, Fracastoro distinguished three forms of contagion and speculated that infections are caused by transferable seed-like beings, seminaria or germs, which could cause infection. Having observed the epidemics of syphilis, plague and typhus that devastated Italy during the 16<sup>th</sup> century, Fracastoro intro-

duced his own theory of disease, the contagious theory. According to his writings, some diseases, such as syphilis and gonorrhoea were only transmitted by direct contact, other diseases were transmitted by fomites as clothing, that had been in contact with the sick and in the third category he placed diseases such as tuberculosis and smallpox capable of infecting persons at a distance from the sick and transmitted by air [1]. For Fracastoro, germs are conceived not as living microorganisms but as chemical substances liable to evaporation and atmospheric diffusion; each disease was specific and had its specific germ; the germ propagated in the tissue of the infected host and caused disease by setting up chemical putrefactive changes in those tissues; in order a germ to produce infection, it must find a corresponding analogy in the tissues of the host [11].

Fracastoro's theory is considered to be the first theoretical statement of the contagious theory of the disease, three centuries before Pasteur's and Koch's researches, a victory of rationalism but in that period a difficult concept for people to accept; they continued to believe in the miasma theory that persisted well into the 1800s.

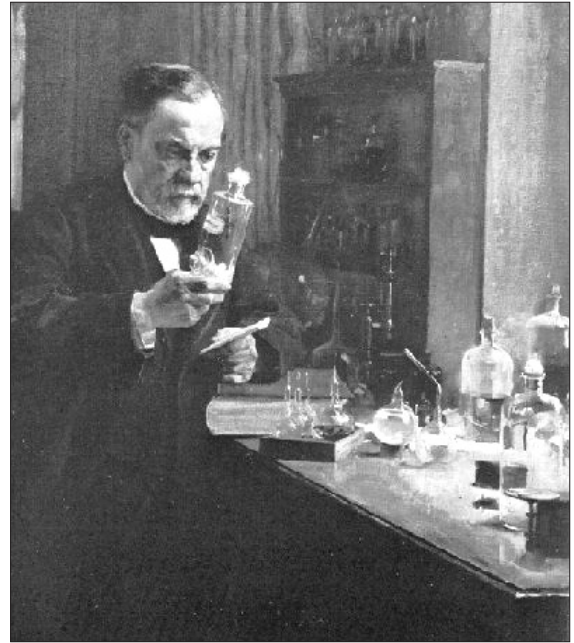
#### *From spontaneous generation to germ theory*

Despite the discovery of the microscopic world by Anton van Leeuwenhoek (1632 – 1723), in the 17<sup>th</sup> century little progress had been made on the road to truth and reason. In that historical period the revival of the spontaneous generation theory was widely accepted by most members of the scientific community. It proposed that simple life arises spontaneously from non living matter (abiogenesis); for example mice can arise from grain and maggots from decaying meat. The idea of spontaneous generation may be tracked back in the teaching of Aristotle in 4<sup>th</sup> century BC. According to this theory stated in *The History of Animals* and in *The Generation of Animals*, living things came from non living things because the non living material contained pneuma or vital force [12].

A strong opponent to that theory was the Italian physician Francesco Redi (1626-1697). In his work entitled *Experiments on the Generation of Insects*, published in 1668, he developed an experiment in order to disprove that maggots arose spontaneously from decaying meat (Figure 1). Redi began by putting pieces of meat into six jars, he covered with lids three of the jars and he left open the other three. The meat in the closed jars decayed but no maggots appeared;



**Figura 1** - The eminent Italian physician Francesco Redi (1626-1697).



**Figura 2** - The French chemist and microbiologist Louis Pasteur (1822-1895).

however maggots and flies appeared in the opened jars. His experiment did not convince the supporters of the spontaneous generation theory which argued that it was unauthentic; the lids excluded air and therefore the “vital” force necessary for spontaneous generation to occur. Redi modified his experiment by putting nets instead of lids on the same jars and no maggots appeared. These results gave a strong blow to the spontaneous generation theory but many scientists still believed that microscopic forms of life were generated from non living substances [13, 14].

The theory of spontaneous generation was finally putting to rest in 1862 when the French chemist Louis Pasteur (1822-1895) proposed a germ theory of diseases, supporting that microorganisms are the cause of diseases (Figure 2). Actually, during that period scientists were working on the notion of the species trying to identify life. If Charles Darwin (1809-1882) went to Galapagos and he theorized on the birth of a new world and on the evolution of species, Pasteur was riveted to his microscope revealing the origin of germs [15].

During 1862 and 1864, Pasteur was working on ferments, carrying out revolutionary experiments and making observations that disproved the spontaneous generation: “Among the questions raised by my research on the ferments in

the narrow sense, none are more worthy of attention than those relating to the origin of ferments. Where do they come from these mysterious agents? This is the problem that has led me to study the so-called “spontaneous generation” [15]. He demonstrated that fermentation and growth of microorganisms in nutrient body did not proceed by spontaneous generation. He boiled meat broth in a flask, heated the neck of the flask in a flame until it became pliable, and bent it into the shape of an S. Air could enter the flask, but airborne microorganisms could not, they would settle by gravity in the neck. As Pasteur had expected, no microorganisms grew. When he tilted the flask so that the broth reached the lowest point in the neck, where any airborne particles would have settled, the broth rapidly became cloudy with life [16]. Pasteur had both refuted the theory of spontaneous generation and demonstrated that microorganisms are everywhere, even in the air; the revolutionary germ theory was a reality [17].

Finally, it was a German scientist Robert Koch (1843-1910) who developed the criteria and procedures necessary to establish that a particular microbe and no other cause a particular disease. His first demonstration with the anthrax bacillus was in 1876. Between 1877 and the end of the century he identified tuberculosis bacillus and vibrio cholerae. In 1884 Koch and Friedrich

Loeffler (1852-1915) formulate four criteria in order to establish a relationship between a causative microbe and a disease. According to this, the microorganism must be found in abundance in all organisms suffering from the disease, but should not be found in healthy animals, it must be isolated from a diseased organism and grown in pure culture, the cultured microorganism should cause disease when introduced into a healthy organism and a microorganism must be re-isolated from the inoculated, diseased experimental host and identified as being identical to the original specific causative agent [18]. The modern concept of disease transmission was born.

## CONCLUSION

The concept of disease transmission and contagion was well established before microorganisms were identified. As the conception upon diseases transmission reflects the society's state of progress, we passed from the miasma theory to the most important concept in the history of modern medicine, the germ theory.

*Key words:* miasma theory, Girolamo Fracastoro, spontaneous generation, Louis Pasteur.

**Conflict of interest:** none

## SUMMARY

From miasma to germ theory we trace the evolution of conceptions in infectious disease transmission. Starting from the unproved theories of contagiousness we move on to miasma theory, conta-

gion theory and spontaneous generation theory up to the revolutionary germ theory of disease transmission.

## RIASSUNTO

*In questo articolo viene tracciata l'evoluzione del concetto di trasmissione delle malattie infettive. Partendo dalla teoria non provata della contagiosità, e passando*

*attraverso la teoria dei miasmi, del contagio e della generazione spontanea, gli autori giungono infine a discutere della teoria "rivoluzionaria" dei germi.*

## REFERENCES

- [1] Magner LN. A history of the life sciences. 3<sup>rd</sup> ed. *Marcel Dekker*. New York. 254-256, 2002.
- [2] Winslow C.E.A. The conquest of epidemic disease: a chapter in the history of ideas. *Wisconsin Press*, London. 85-86, 1980.
- [3] Sabbatani S., Fiorino S. The plague of the Philistines and other pestilences in the Ancient World: exploring relations between the religious-literary tradition, artistic evidence and scientific proof. *Infez. Med.* 18, 3, 199-207, 2010.
- [4] Jastrow M. The religion of Babylonia and Assyria. *Bibliolife*, South Carolina. 586, 2009.
- [5] Dawson G. Healing. Pagan and Christian. *Macmillan*, New York. 85, 1936.
- [6] Hippocrates. On air, waters and places. In *The Medical Works of Hippocrates* (Chadwick J., Mann W.N. transl). 301, 1950. *Blakwell Scientific Publications*, Oxford.
- [7] MacLeod R, Lewis M.J. Disease, medicine and empire: perspectives on western medicine and the experience of European expansion. *Routledge*, London. 182, 1988.
- [8] Vitruvius. The Ten Books on Architecture. Translated by Morgan M.H. *Dover Publications*, New York. 331, 1960.
- [9] Sabbatani S., Fiorino S. The Antonine Plague and the decline of the Roman Empire. *Infez. Med.* 17, 4, 261-275, 2009.
- [10] Tsiamis C., Poulakou-Rebelakou E., Tsakris A., Petridou E. Epidemic waves of the Black Death in the Byzantine Empire (1347-1453 AD). *Infez. Med.* 19, 3, 194-201, 2011.
- [11] Brock T.D. Milestones in microbiology. *ASM*, Washington DC. 69, 1999.
- [12] Lennox J. Aristotle's Philosophy of biology: studies in the origins of life science. *Cambridge Press*, New York. 229-258, 2001.
- [13] Shimeld L.A., Rodgers A. Essentials of diagnos-

tic microbiology. *Delmar Publishers*. New York. 7, 1999.

[14] Mancini M., Nigro M., Ippolito G. Lazzaro Spallanzani and his refutation of the Theory of Spontaneous Generation. *Infez. Med.* 15, 3, 199-206, 2007.

[15] Debré P. Louis Pasteur. Translated by E. Forster. 1998, pp 148-149. Johns Hopkins University Press, Baltimore.

[16] Levine R, Evers C. The slow death of spontaneous generation (1668-1859). Disponibile in rete all'indirizzo: [http://www.accessexcellence.org/RC/AB/BC/Spontaneous\\_Generation.php](http://www.accessexcellence.org/RC/AB/BC/Spontaneous_Generation.php).

[17] Sabbatani S. The Semmelweis reasoning and the puerperal fever. *Infez. Med.* 16, 1, 49-61, 2008.

[19] Brock T. Robert Koch: a life in medicine and bacteriology. *ASM, Washington D.C.* 364, 1999.