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Review

What's in a Name? Hellenic Origins of Microbiological Nomenclature

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Abstract: Our intention was to trace the origins of names that every microbiologist comes to pronounce or write down in her/his daily practice and, particularly, to elucidate the etymological debt of this medical field to the two great languages of classical antiquity, Greek and Latin. According to the system of binomial nomenclature established by Linnaeus in the 1750s to give a unique name to each species, consisting of two terms, the name of the genus and the name of the species, combinations were based on Greek and Latin. The two major cocci consist of a literally classical example. Streptococci, named so by Bilroth from the Greek word "*στρεπτόν*—strepton" (necklace), and staphylococci, baptised by Ogston from "staphyli—*σταφύλι*" (grape), were both so named due to their appearance under microscopy. Two well-known species of these genera bear Latin names denoting colour, greenish for *S. viridans* and golden for *S. aureus*. Other bacteria display the discovering scientist like, *E. coli* for Escherich, *Brucella* from Bruce, or *Pasteurella* from Louis Pasteur. Similar pathways also exist for viruses, even back to Hippocrates, like Herpesviruses from "*έρπης*—herpes" (creeping) or Arenaviruses from "*arena*—sand", and fungi, as mycology itself originates from "*μύκης*—myces", Greek for fungus, and *Aspergillus* from the verb "*aspergo*" (to sprinkle).

Keywords: microbiology; names; etymology; classification; history of medicine; historical aspects

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1. Introduction

The title's question is Shakespearian:

"What's in a name? That which we call a rose
By any other word would smell as sweet."

This is what Juliet tells Romeo in the second Act of the eponymous play (II, ii, 1–2). In the case of microorganisms, however, we cannot disguise our pride and satisfaction, being Greek physicians, when, reading medical magazines or attending congresses, we notice the large number of terms of Greek origin. Few, if any, of our fellow colleagues from across the globe would consider this sense of pride as a token of chauvinism, since they certainly experience similar feelings when they hear of a disease or microorganism bearing the name of a scientist from their country of origin. They are combined with Latin words, but the Greek origin is unmistakable.

2. Bacteria Nomenclature

The two major cocci comprise a literally classical example. One of the greater personalities in surgery, Theodor Billroth (1829–1894), left his mark in the history of medicine with the technique for a stomach operation that bears his name. A man of many talents, he was quite a proficient amateur violin player, as his close friend Johannes Brahms would certainly confirm. Most important, from the microbiological point of view, is his contribution to onomatology. He was also an amateur yet extremely competent microbiologist, and by observing streptococci, he named them thus from the Greek words "*στρεπτόν*—strepton" (necklace) and "*κόκκος*—coccus" (granule) due to their chain-like appearance [1,2].

It was also in the case of another surgeon from Scotland, Sir Alexander Ogston (1844–1929), who was inspired by the Greek word "*σταφύλι*—staphyli" (grape), to name thus Staphylococci due to their morphology under microscopy, two more Greek words, incidentally. He achieved this discovery with a Zeiss microscope and the methyl-aniline dye used by Koch, converting the shed behind his house into a laboratory [3].

The naming of the most known species of the above genera, *Streptococcus pneumoniae* and *Staphylococcus epidermidis*, is completely Greek, while others bear Latin names denoting colour, greenish for *Streptococcus viridans* and golden for *Staphylococcus aureus*. All these were fabricated according to the so-called Linnaean system of binomial nomenclature established by Carl von Linné, Carolus Linnaeus in Latin, introduced in the 1750s to give a unique name to each species, consisting of two terms, the name of the genus and the name of the species [4]. The binomial combinations are based on the two main classical languages, Greek and Latin. The classification according to Ferdinand Cohn, in the year 1872, recognised six bacterial genera: *Micrococcus*, *Bacterium*, *Bacillus*, *Vibrio*, *Spirillum*, and *Spirochaeta* [5]. With the exception of "vibrio", which comes from the Latin word "*vibrare*" (to wave), all of them stem from Greek. The Latin word "*spira*" (coil) of *Spirillum* and *Spirochaeta* is derived from the Greek "*σπείρα*—spira". The word bacteria, plural of bacterium, is transferred to Latin from the Greek word "*βακτηρία*—vakteria" (cane, walking stick) due to their morphologic appearance; the term was introduced in scientific bibliography in 1838 by Christian Gottfried Ehrenber, Professor of Medicine at Berlin University [6].

Alongside the language, Greek mythology and Homeric sagas, in particular, have been an inspiration in many aspects and provided a variety of words, terms, and expressions that are used quite commonly in everyday life. Examples in medicine include "the Trojan horse" to describe the carefully masked and apparently "innocent" carriage of dangerous cargo, for example, in the form of HIV-1 by dendritic cells, or "the Achilles tendon", which is used to denote identified weak points in anatomy or physiology. Therefore, it comes as no surprise to see a microorganism named from a similar source. Proteus, son of Poseidon, maritime deity of rivers and "*old man of the sea*", as Homer puts it, "*Πρωτέος ἰφθίμου θυγάτηρ ἁλίοιο γέροντος*" [the daughter of mighty Proteus, the old man of the sea] [7], was famous for his transformations. This was the name that microbiologist Gustav Hauser (1856–1935), Professor at Erlangen University, chose for bacteria isolated from putrefied meat in 1885 [8,9].

This same origin applies for syphilis. The disease arrived from the New World together with Columbus's sailors. The first to see the disease in Europe was Ruiz Diaz de Isla, a Barcelona-based physician, who wrote in a book that Columbus's crew contracted the disease in Hispaniola in 1492 and that he had observed its rapid spread through Barcelona upon his return. He called it *Morbo serpentine*, literally meaning "snake disease", which he described also as "the hideous, dangerous, terrible disease". Then, war contributed to its spread throughout Europe. This happened in 1495, when King Charles VIII of France invaded Italy, targeting Naples, with the French calling the disease "*Mal du Neaples*" and "*Spanish disease*", which led to Italians replying with the names "*Morbo gallico*" and "*mal di Francia*". The name of *Morbus Gallicus*, i.e., French disease, was prevailing, and the hurt feelings of Jacques de Béthencourt from Rouen led him to propose "*lues venereal*" (venereal plague) from the name of goddess Venus. This led to the term "*venereal*" applying to all diseases transmitted through sexual intercourse [10]. All these names mirrored chauvinistic rivalries, as it becomes apparent from the fact that the Dutch called it "Spanish disease", the Russians "Polish disease", and in Portugal, as well as in Scotland, the name "English disease" was employed [10]. And all the names, so far, were in Latin or in the native language of their creators. But the origin can be traced to a Greek word, or, rather, to a Greek name, which the disease finally acquired, the name we use today, in 1530. A physician, philosopher, and poet, a true example of a Renaissance man, Girolamo Fracastoro (1478–1553)—Hieronymus Fracastorius in Latin—besides his contribution to the study of infectious diseases (De Contagione, 1527), described the symptoms of the disease and

suggested the therapeutic use of gum guaiacum—hence *gumma*, *gummae*—and finally named the disease through a poem of 3300 verses in Latin. The name he chose, however, was of a fictitious ancient Greek shepherd called Syphilus

"... A shepherd once (distrust not ancient fame)

Possest these Downs, and Syphilus his Name..." [11]

Therefore, almost inevitably, given the German affection for Greek antiquity as so vividly expressed by Goethe and Nietzsche, among others, when the pathogen was identified by microscopy in syphilitic ulcers by Fritz Schaudinn and Erich Hoffmann at the Charité hospital in Berlin in 1905, they gave it a Greek name, "*spirochaete*", from two Greek words, "*σπείρα*—spira" (coil) and "*χαίτη*—heti" (mane). With the addition of the Latin "*pallida*—pale", it became *Spirochaeta pallida*, and then the latter was renamed as *Treponema pallidum* from the ancient words **"***τρέπω*—trepo" (turn) and "*νῆμα*—nima" (thread) [12].

Now, we should focus on one of the most common nosocomial pathogens and a source of terror in departments of immunocompromised patients, namely *Pseudomonas* spp. Yet another German scientist, the botanist Walter Migula (1863–1938), Professor of Karlsruhe University, in his two-volume work *System der Bakterien: Handbuch der Morphologie, Entwicklungsgeschichte und Systematik der Bakterien* (1897–1900), coined the term *Pseudomonas* for a genus he described in 1894. The term consisted of the Greek word "*ψευδο*—pseudo" (false) and the word "*μονάς*—monas", referring not to the Greek word meaning "*unit*" but the name *Monas,* assigned in 1773 to a genus of "*Infusoria*" by the Danish naturalist Otto Friedrich Müller (1730–1784). *Infusoria* are ciliate freshwater microorganisms, including ciliates, currently classified into Protista. Migula probably so named *Pseudomonas* because of the resemblance of its cells to those of the microorganisms in terms of size and motility. The second name of the most known species, "*aeruginosa*" has nothing to do with air; instead, the name stems from the Latin adjective "*aerugo*", meaning verdigris, the blue-green colour of oxidated copper ("*copper rust*"), similar to the colour of the Statue of Liberty that the French donated to the people of the United States of America. Additionally, the name initially given to the species by Walter Migula was *Pseudomonas pyocyanea* from the Greek words "*πύον*—pion" (pus) and "*κυανή*—kiani" (blue) since most *P. aeruginosa* strains produce the pigment pyocyanin that distinguishes them from all other *Pseudomonas* strains on Petri dishes [13,14].

As a general rule, a word of Greek origin would be used for the genus name and a word of Latin origin would be used for defining the species. However, this tended to change over the years, with the first name coming from the scientist who discovered the genus. This started with the most common pathogen causing urinary tract infections, as in the case of a paediatrician with the same Christian name as Bilroth, Theodor Escherich (1857–1911), who was teaching at Vienna and Munich Universities. He described a bacterium in his 1886 book *Die Darmbakterien des Säuglings und ihre Beziehungen zur Physiologie der Verdauung* (Enterobacteria of infants and their relation to digestion physiology), giving the name "bacterium coli commune", from the ancient Greek word "*κόλον*—colon" (intestine), which was later named *Escherichia coli* as a tribute to him by Aldo Castellani and Albert John Chalmers [15,16].

Two other famous pathogens were named after another pioneer, known with his surname and the Greek names for the respective diseases. Albert Neisser (1855–1916) wanted to follow internal medicine, but the only vacant post at the time was in dermatology/venereal diseases at Erlangen University. He thus worked on leprosy and is associated with its discovery alongside Hansen. By the year 1873, Norwegian Gerhard Henrik Hansen (1841–1912) had already published an article on the disease, having observed the bacteria in scrapings. This was actually the first time that a specific microorganism was incriminated as the cause of a disease [17]. Although Hansen could not cultivate the microorganism, he named it *Mycobacterium leprae* due to its similarity to tuberculosis, which Robert Koch had described. In the case of leprosy, all words originated from Greek, "*μύκης*—mikis" (fungus) and bacterium and leprosy from the Ancient Greek verb "*λέπω*—lepo", meaning

desquamate. The first documentation of the word is in the 13th century Ancrene Wisse manual for nuns (Anchoresses in old English), when a subject was described as "*leper*" [18]. In 1879, Hansen gave patient tissues to Neisser, who managed to successfully stain the bacteria, essentially sharing the discovery. It was also he who discovered the pathogenesis of leprosy [19].

There is no controversy, however, regarding the discovery of gonorrhoea, as he initially referred to the pathogen as **"***Gonorrhoea specific micrococcus*"; eventually, the pathogen acquired his own name, "*Neisseria gonorrhoeae*" [20]. The term pre-existed in the Old Testament, but it is debatable whether hygiene rules stemming from Leviticus (When any man hath a running issue out of his flesh, because of his issue he is unclean. . .Leviticus 15:2—"*και ακάθαρτος έσεται ο γονορυής*" in the Greek translation) refer to the sexually transmitted disease or simply to spermorrhoea as in the Bible's translation that bears the name of the French cities, Rheims and Douai (1582). There it reads "the man having issue of seed shall be unclean". The Septuagint, i.e., the Greek translation of the Old Testament, also known by the Roman numerals LXX for seventy, had been completed by the first century B.C., while Galen introduced the term "*gonorrhea*" in 149 A.D., still being dubious if it was indeed meant to describe gonococcal urethritis. The fact that neither satirical Latin poets, like Juvenal or Martial, nor early medieval texts like Chaucer's *Canterbury Tales* or Boccaccio's *Decameron,* make such mention enhances these doubts, since given their subjects, which include frequent references to sexual encounters and overall lifestyle, they would hardly fail to omit such a state [21].

Neisser's name was also given to the meningitis pathogen, described initially in 1884 from a cerebrospinal fluid specimen by two Italian pathologists, Ettore Marchiafava and Angelo Celli [22]. Anton Wiechselbaum identified meningococcus, also from cerebrospinal fluid, in 1887, naming it "Diplococcus intracellularis meningitides" [23] until it finally was given Neisser's name, always keeping the rule of maintaining the Greek name for the disease, with meningitis meaning inflammation of the "*μήνιγγες*—meninges" [24].

In the decades that followed, a far greater number of microorganisms acquired their name from the scientist who initially made the discovery, as it was not always a doctor of medicine that was the first one to describe them. We have, thus, *Salmonella,* from Daniel E. Salmon, an American veterinarian and the first man to be awarded this degree in the United States (1850–1914); *Brucella,* from Sir David Bruce, a Scottish pathologist and microbiologist (1855–1931); *Bordetella,* from the Belgian immunologist and microbiologist Jules Bordet (1870–1961), Nobel Prize laureate for Medicine in 1919; *Pasteurella,* from Louis Pasteur, who had studied physics and chemistry, of course; *Rickettsia*, from Howard Taylor Ricketts (1871–1910); and many more [24]. The list increases in size even more with the name changes, a quite frequent occurrence in microbiology, which leads to a physician encountering the microorganism called at first *Bacterium bookeri* when isolated from pleuritic fluid followed by three different names during his hospital life. He was reading about it under the name of *Pseudomonas maltophilia* while serving as a house officer; then, as a registrar, it had become *Xanthomonas maltophilia,* and when he finally achieved consultant status, it was called *Stenotrophomonas maltophilia*! Yet, all genus names were Greek in origin, with *Xantho* from "*ξανθός*—ksanthos" (blond) and *Stenotropho* from "*στενό*—steno" (narrow) and "*τροφός*—trophos" (feeder). The species name was 50% Greek, synthesised by the verb "*φιλώ*—filo" (love), meaning loving, and "*maltum*", the Latin word for malt [25].

3. Virus Nomenclature

The naming of viruses is more "technical" as, since 1966, they are named according to the International Committee on Taxonomy of Viruses (ICTV). Each virus carries an official name consisting of the family, genus, and species name [26]. Virus names are usually in English or reflect the area of origin (Ebola, Zika), the host and the disease, or an acronym, as in the case of SARS-CoV-2, the causative agent of COVID-19, whose name is an acronym for Severe Acute Respiratory Syndrome Coronavirus 2 [27]. There are, however, quite a few examples of classical Greek origin, even dating back to Hippocrates, like Herpesviruses, where "*έρπης*—herpes" came from the verb "*έρπειν*—erpin" (to creep) [28];

the Enteroviruses, from "*έντερον*—enteron" (intestine); and the Hepatitis viruses, from infection of the "*ήπαρ*—hepar" (liver). This also applies to Flaviviruses, Papillomaviruses, or Arenaviruses from "*arena*—sand", as the part of the Roman amphitheatre was also called (another Greek word, incidentally!), where gladiators fought for their lives. Even miscegenations exist, for instance, Orthopoxviruses, from the Greek "*ορθός*—orthos" (true, correct) and "*pox*", exanthematous disease, an English spelling alteration of the Latin word "*pockes*", plural of "*pocke*", meaning pocket but also pustule [29].

Many viruses are named after the disease they cause. A classic example is the poliomyelitis virus, from the name given to the disease in 1874 by the German physician Adolph Kussmaul (1822–1902) from the Greek words "*πολιός*—grey" (whitish, particularly for hair) and "*μυελίτις*" (myelitis), the inflammation of the spinal cord's gray matter [30]. The Latin term "*influenza*" derives from the Italian word "*Influenza*", which originated from the Latin word "*influentia*", meaning influence, visitation. The term was used to describe flu outbreaks because of the belief that epidemics were due to the influence of the stars, a very common belief in late Roman times, as reported about several pandemics, including the Antonine and Justinian plague [31]. The pandemic of 1733, one of the worst in the 18th century, originated in Italy and quickly spread to all European countries. The appearance of the disease in England during this particular pandemic coincided with the addition of the word to the English vocabulary [32].

4. Protozoa Nomenclature

Protozoa, a group of single-celled eukaryotes, were introduced by Georg Goldfuss, in 1818 as a class within the Animalia, and the term itself consisted of two Greek words: "*πρώτο*—proto" (first) and "*ζώα*—zoa" (animals). Many human pathogens within this class also bear Greek names, like *Entamoeba histolytica,* stemming from Amoeba, a name given by the naturalist Jean-Baptiste Bory de Saint-Vincent (1778–1846), who was famous because of the abbreviation Bory used as an author when a name is referred to in Botany. Bory gave the name "*amibe*", from the Greek word "*αμοιβή*—amivi", meaning reward, but also change, in Ancient Greek [33]. The term "*histolytica*", incidentally, is also the result of the words "*ιστός*—histos" (tissue) and the verb "*λύω*—lio" (dissolve, destroy). In concordance, the French microbiologist Alfred François Donné (1801–1878) gave the name *Trichomonas hominis* to the microorganism he isolated in 1835 from purulent vaginal discharge, from two Greek words, "*μονάς*—monas" and "*θριξ*—thriks" (hair) due to the flagella it bore [34]. A similar course was followed by John Everett Dutton in 1902, who, while working in Africa, coined a name for *Trypanosoma gambiense* when he combined the Greek words "*τρύπανο*—tripano" (drill) και "*σῶμα*—soma" (body) with the name of the land where he isolated it. *Trypanosoma* is a genus of protozoa causing various diseases. The same Greek words combined with the scientist's surname are also used for *Trypanosoma cruzi*, to honor the Brazilian scientist Oswaldo Cruz, and as the aetiologic agent of Chagas disease, as well as for *Trypanosoma brucei*, the aetiologic agent of sleeping sickness. Similarly, *Brucella* spp. were named after Sir David Bruce [35]. Other examples include *Toxoplasma gondii*, a name that was coined in French by Charles Nicolle and Louis Manceaux in 1909 and "Toxoplasm", derived from the Greek words "*τόξον*—toxon" (bow) and "*πλάσμα*—plasma" (creature), referring to the organism's lunate shape [36].

5. Fungus Nomenclature

Regarding fungi, although the term fungus comes from the Latin word for mushroom, the scientific branch itself dealing with fungi, "mycology", has a Greek root, as "*μύκης*—myces" is the Greek ancient word for fungus. Other frequently used terms in mycology, such as "*υφή*—hypha" (web), "*σπόρια*—spores" (seeds), zygomycetes, and hyphomycetes, originate from Greek as well. The common root "*μύκης*—mykis", is an Ancient Greek word meaning mushroom, particularly of the Amanita genus, and describing any round, nodular body [37]. The Latin word **"***fungus***"** was attributed to Virgil and is first mentioned in the first of his four poetical books bearing the—also Greek—title *Georgics* ("*γεωργικά*—georgika"

(agricultural)) in the verse "... Scintillare oleum et putris concrescere fungos..." [38]. The Latin word is believed to be derived from the Greek "*σφόγγιον*—sfoggion", the Attic form of "*σπόγγος*—sponges" (sponge). Both Greek and Latin nomenclature are accurate in terms of fungus morphology in nutrient substrates, as well as in the macroscopic morphology of the lesions they cause in a variety of organs, in which centrifugal growth of the fungus and often a spongy texture of the tissue are observed.

The most important fungus, in terms of its contribution to medical therapeutics history, is definitely the one leading to the discovery of penicillin. In the words of Sir Alexander Fleming, a quote both modest but also a realistic assessment of his discovery, "When I woke up just after dawn on 28 September 1928, I certainly didn't plan to revolutionise all medicine by discovering the world's first antibiotic, or bacteria killer. But I guess that was exactly what I did". [39]. Actually, it was a French army doctor, Ernest Duchesne (1874–1912), whose thesis in 1894 had the title **"***Contribution à l'étude de la concurrence vitale chez les micro-organismes: antagonisme entre les moisissures et les microbes***"** (it is also of note that three out of four words in the title of his thesis, namely "microorganisms", "antagonism", and " microbes**"**, had a Greek origin as well), who discovered penicillin. However, when he posted it to the Pasteur Institute in Paris, nobody paid attention to the paper of a young physician from the Lyon Military Medicine School [40]. It dealt with the fungus *Penicillium glaucum,* used in "blue" cheeses (Gorgonzola, Bleu de Bresse, etc., though not with Roquefort, the work of *Penicillium roqueforti*). These fungus spores were placed in a way that looked like a paintbrush, and this was why all these fungi acquired the name *Penicillium*, from the Latin word "*penicillus*", also the root for pencil in English [40,41].

Aspergillus owes its name to object similarity too. It came from the Latin "*Aspergillum*", stemming from the verb aspergo (to sprinkle) and, given to an implement in the form of a brush or of a rod with a perforated container, a holy water sprinkler in the Catholic Church. It was fitting that the scientist who applied the name to the fungus due to its appearance was an Italian, Pier Antonio Micheli (1679–1737), just as true to the definition of an Enlightenment man precisely as Fracastorius fitted the image of a multi-talented Renaissance man. Micheli, being a priest as well as a biologist, drew from his ecclesiastical experience for the benefit of his scientific curiosity and, due to his observing power, he was the man who gave the name to this fungal species in the year 1729 [42].

The most frequently isolated fungus, *Candida albicans*, was initially, in 1853, called "*Oidium" albicans* by the French anatomist and histologist Charles-Philippe Robin, widely considered as the Father of Mycology, and "*ωίδιον*—oidium" (ovule). It came to be *Candida albicans*, which is in fact a tautology since both Latin words are similar, with "*albicans*" meaning "whiteish" and "*Candida*" being the feminine form of the adjective "*candidus*", which means "*white, dressed in white*" but also "*transparent*" [43].

A pathogen that came to spectacular prominence and with which even lay people and non-medical experts became familiar at the dawn of the AIDS epidemic was a microorganism initially classified as a protozoon. The fatal condition for immunocompromised individuals became known as *Pneumocystis carinii* pneumonia. *Pneumocystis* organisms were first reported by Chagas in 1909, and their principal pathogen was named *Pneumocystis carinii* from the surname of Antonio Carini (1872–1950), an Italian bacteriologist and professor who worked in the public health sector of São Paulo, Brazil. The word "Pneumocystis" derives from two Greek words, "*πνεύμων*—pneúmōn", meaning lung, and "*κύστις*—cystis", i.e., cyst. The disease is termed pneumonocystic pneumonia or pneumonocystosis and the origin of both these words is Greek. From its discovery, *Pneumocystis* was widely thought to be a protozoon having similarities in microbe morphology and host pathology while lacking typical fungal phenotypic features. However, DNA analysis in 1988 demonstrated that *Pneumocystis* is a fungus. The subspecies affecting humans had already been renamed *Pneumocystis jiroveci* in 1976, in honor of the Czech parasitologist Otto Jirovec, who was initially credited with describing the microorganism in humans. It was renamed *P. jirovecii* Frenkel, once again, in 1999 [44].

6. Conclusions

The two classical languages of antiquity, Greek and Latin, provided the cornerstone that laid the foundation for terms used across all sciences. They widely prevailed in medicine and even more so in the field of microbiology. For two consecutive centuries, their role in creating the Golden Age for the discovery and naming of aetiologic factors of infection was detrimental. The heritage of Ancient Greek will remain precious and immortal through the ages as long as medicine and physicians, patients and diseases, but above all knowledge and education, continue to exist. This is not meant to claim propriety or superiority in these names, terms, and fields, for nobody would ever dare to contemplate or propose anything different than the universal and absolutely dogmatic truth that science as well as art belongs to Humanity and Humanity alone. It is simply with certain, hopefully forgivable, pride to dwell on the roots of words used everyday in hospitals, laboratories, and textbooks all over the world, knowing that these words originated from a small piece of land at the shores of the Mediterranean Sea, where we still live and communicate, using words like these in our daily vocabulary.

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