1

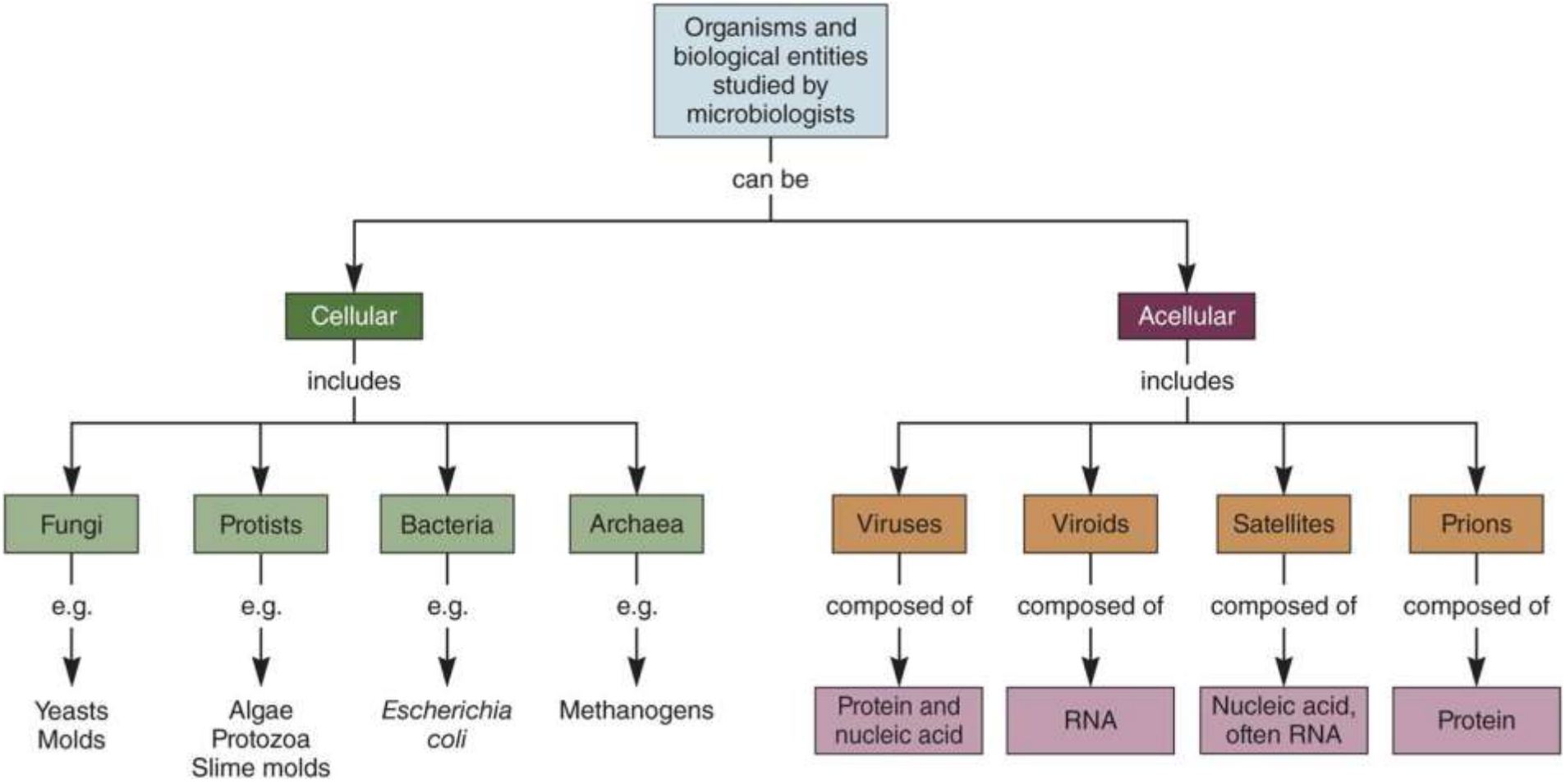
The Evolution of Microorganisms and Microbiology

The Importance of Microorganisms

- Most populous(كثيف بالسكان/مزدحم) and diverse group of organisms
- Found everywhere on the planet
- Play a major role in recycling essential elements
- Source of nutrients and some carry out(تقوم بـِ/تُنفذ) photosynthesis
- Benefit society by their production of food, beverages(مشروبات), antibiotics, and vitamins
- Some cause disease in plants and animals

Members of the Microbial World

- Organisms and acellular entities too small to be clearly seen by the unaided eye
  - some < 1 mm, some macroscopic
- These organisms are relatively simple in their construction(بنائهم) and lack highly differentiated cells and distinct tissues

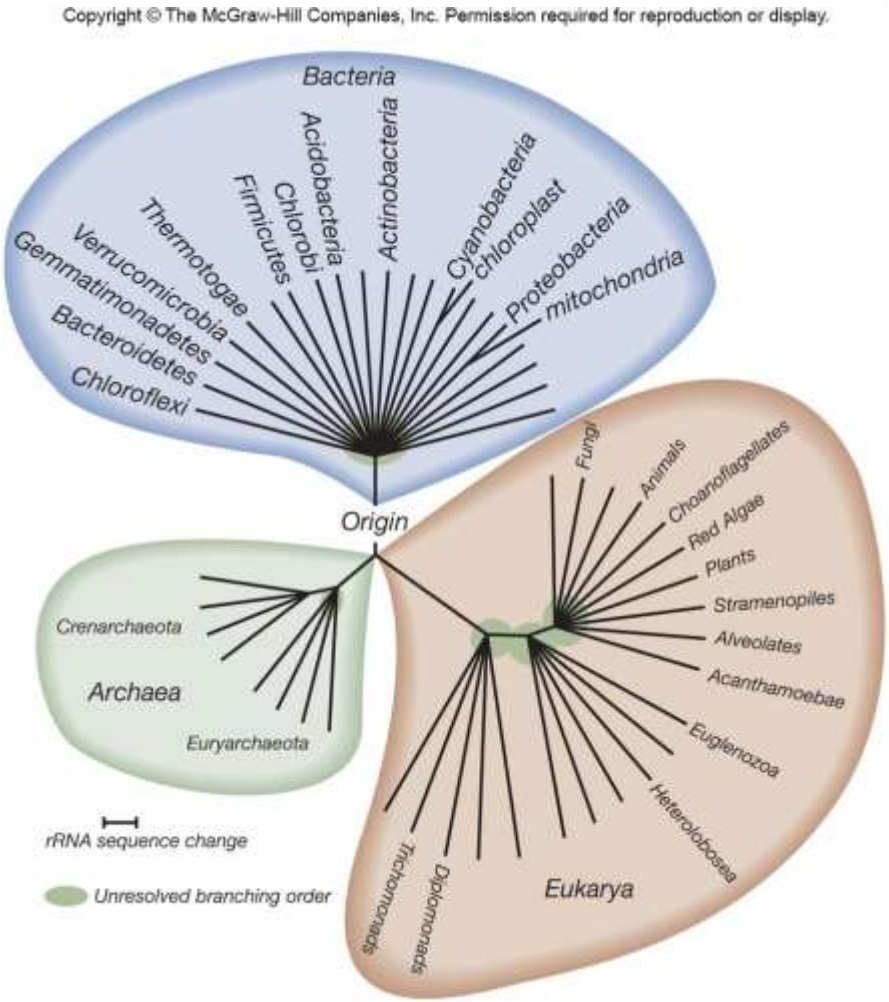


Type of Microbial Cells

- Prokaryotic cells lack a true membrane-delimited nucleus
  - this is not absolute!
- Eukaryotic cells have a membrane-enclosed nucleus, are more complex morphologically, and are usually larger than prokaryotic cells

Classification Schemes

- Three domain system, based on a comparison of ribosomal RNA genes, divides microorganisms into
  - *Bacteria* (true bacteria),
  - *Archaea*
  - *Eukarya (eukaryotes)*



Domain *Bacteria*

- Usually single-celled
- Majority have cell wall with peptidoglycan
- Most lack a membrane-bound nucleus
- Ubiquitous(واسعة الانتشار) and some live in extreme environments
- Cyanobacteria(البكتيريا الزرقاء) produce significant amounts of oxygen

Domain *Archaea*

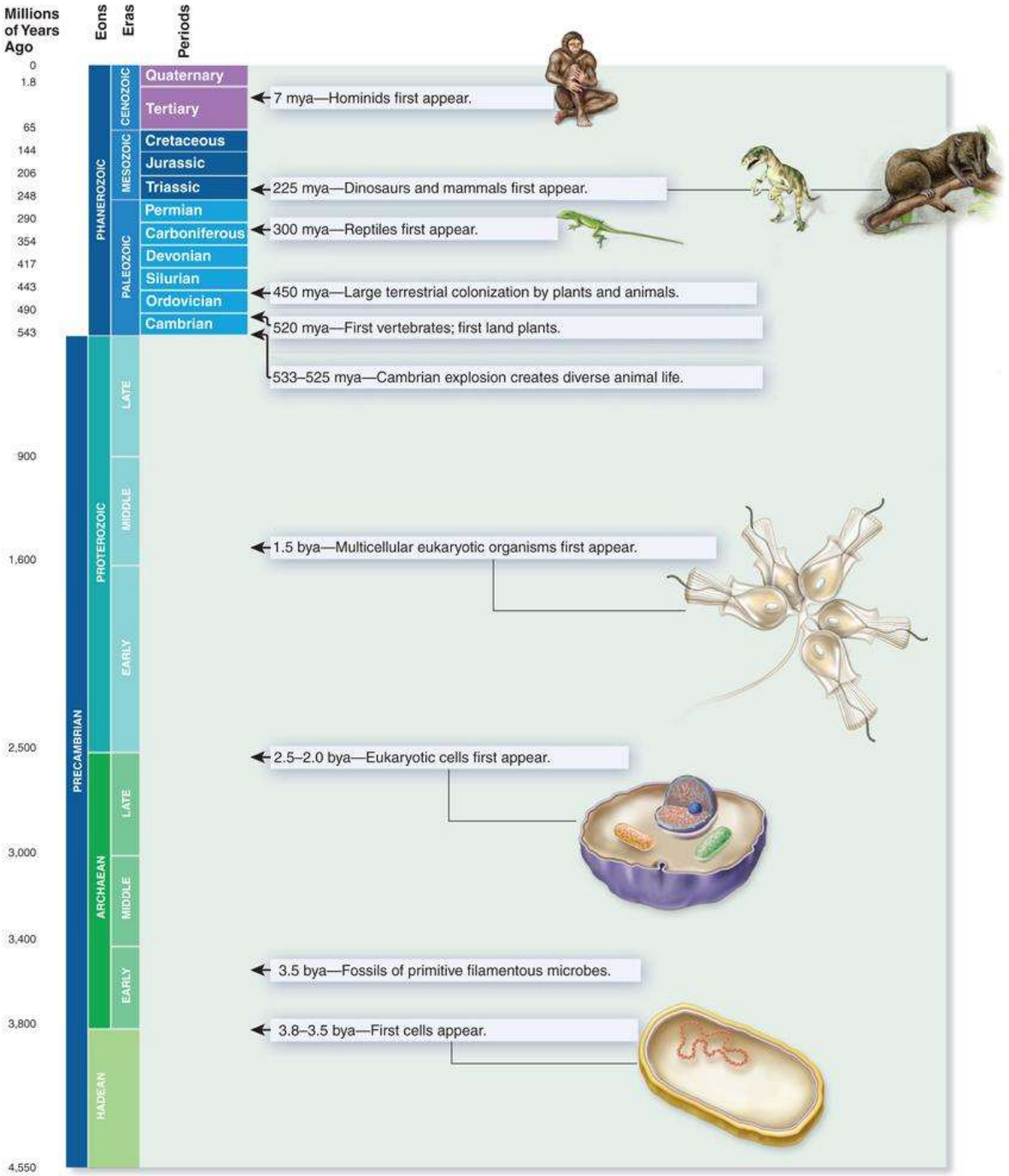
- Distinguished from *Bacteria* by unique rRNA gene sequences
- Lack peptidoglycan in cell walls
- Have unique membrane lipids
- Some have unusual metabolic characteristics
- Many live in extreme environments

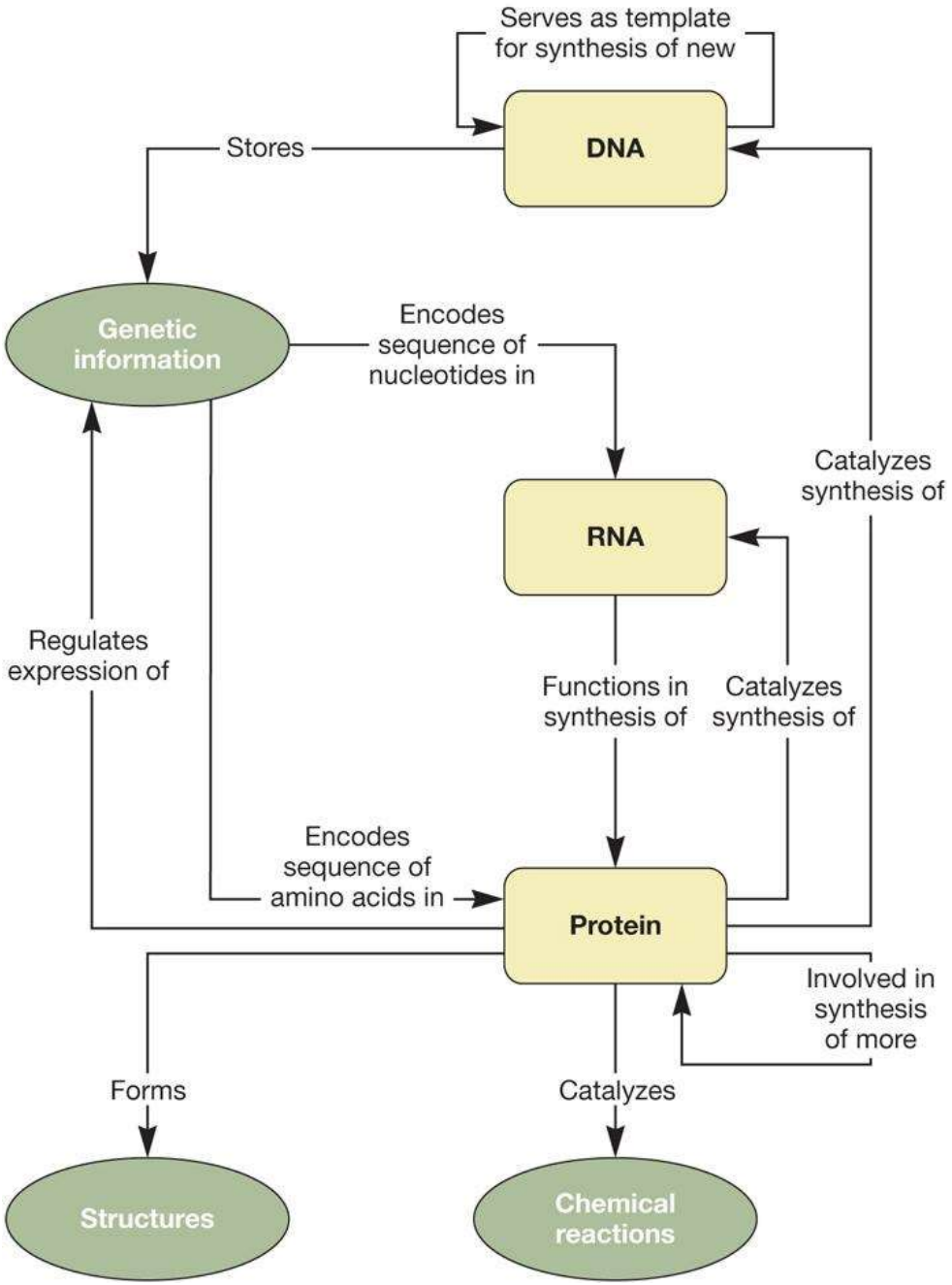
Domain *Eukarya* - *E*ukaryotic

- Protists – generally larger than *Bacteria* and *Archaea*
  - algae – photosynthetic
  - protozoa – may be motile, “hunters, grazers”
  - slime molds – two life cycle stages
  - water molds – devastating(مدمر) disease in plants
- Fungi
  - yeast - unicellular
  - mold - multicellular

Acellular Infectious Agents

- Viruses
  - smallest of all microbes
  - requires host cell to replicate
  - cause range of diseases, some cancers
- Viroids and virusoids
  - infectious agents composed of RNA
- Prions – infectious proteins





Evolution of Cellular Microbes

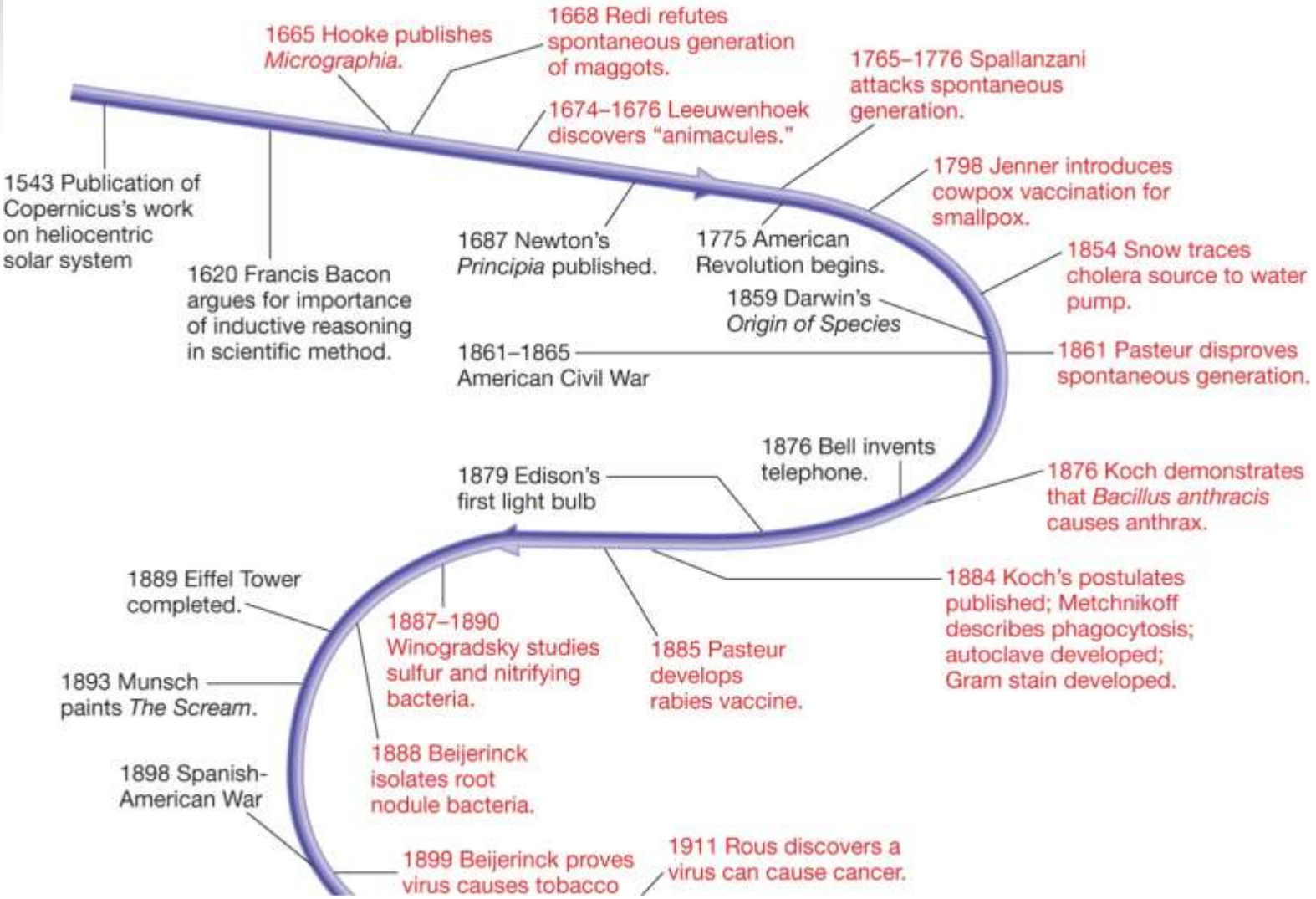
- Mutation of genetic material led to selected traits
- New genes and genotypes evolved
- *Bacteria* and *Archaea* increase genetic pool by horizontal gene(plasmids(في البلازميدات)) transfer within the same generation

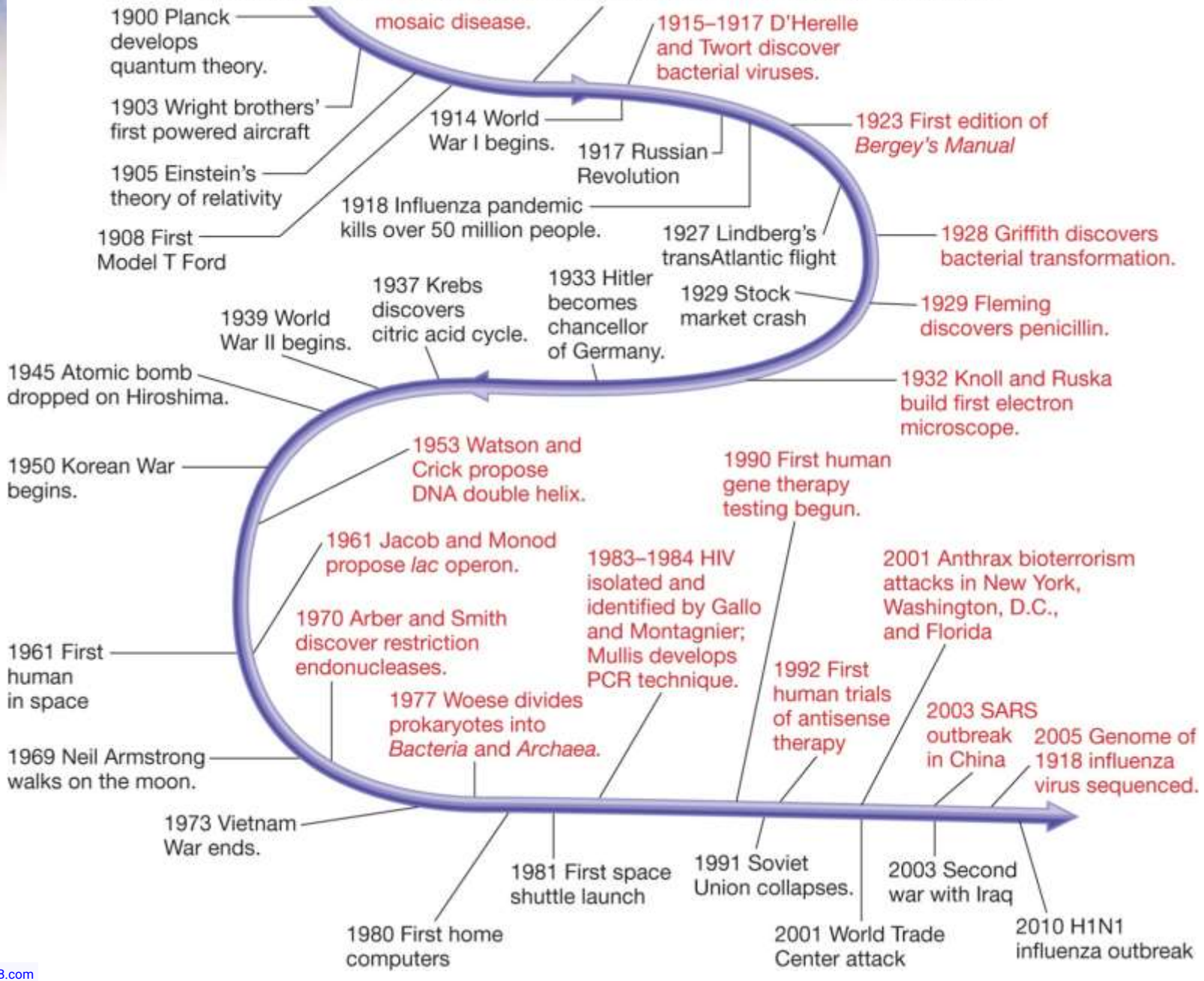
Microbial Species

- Eukaryotic microbes fit definition of reproducing isolated populations
- *Bacteria* and *Archaea* do not reproduce sexually and are referred to(يُشار اليها)as strains(سلالات)
  - a strain consists of descendents of a single, pure microbial culture
  - may be biovars, serovars, morphovars, pathovars
- binomial nomenclature(التسميات ذات الحدين)
  - genus and species epithet(لقب/كنية)

Microbiology - Origins

- Study of microorganisms
- Tools used for the study
  - Microscopes(المجاهر)
  - culture techniques
  - molecular genetics
  - genomics(المجموع الوراثي/المحتوى الوراثي)



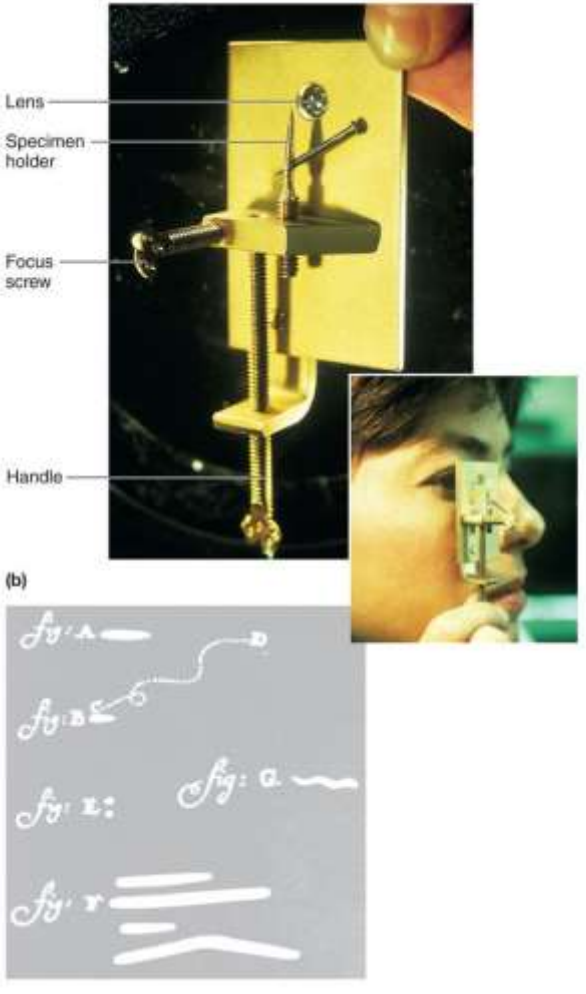


Discovery of Microorganisms

- Antony van Leeuwenhoek (1632-1723)
  - first person to observe and describe microorganisms *accurately*

(a)

© Bettmann/Corbis



(b)

(c)

b: © Kathy Park Talaro/Visuals Unlimited c: © Science VU/Visuals Unlimited

The Conflict over Spontaneous Generation(الذاتي(الخلق)الصراع على التولد)

- Spontaneous generation
  - Idea that living organisms can develop from nonliving or decomposing matter
- Francesco Redi (1626-1697)
  - discredited spontaneous generation
  - showed that maggots(الديدان) on decaying meat(اللحوم المتحللة) came from fly eggs

But Could Spontaneous Generation Be True for Microorganisms?

- John Needham (1713-1781)
  - his experiment:

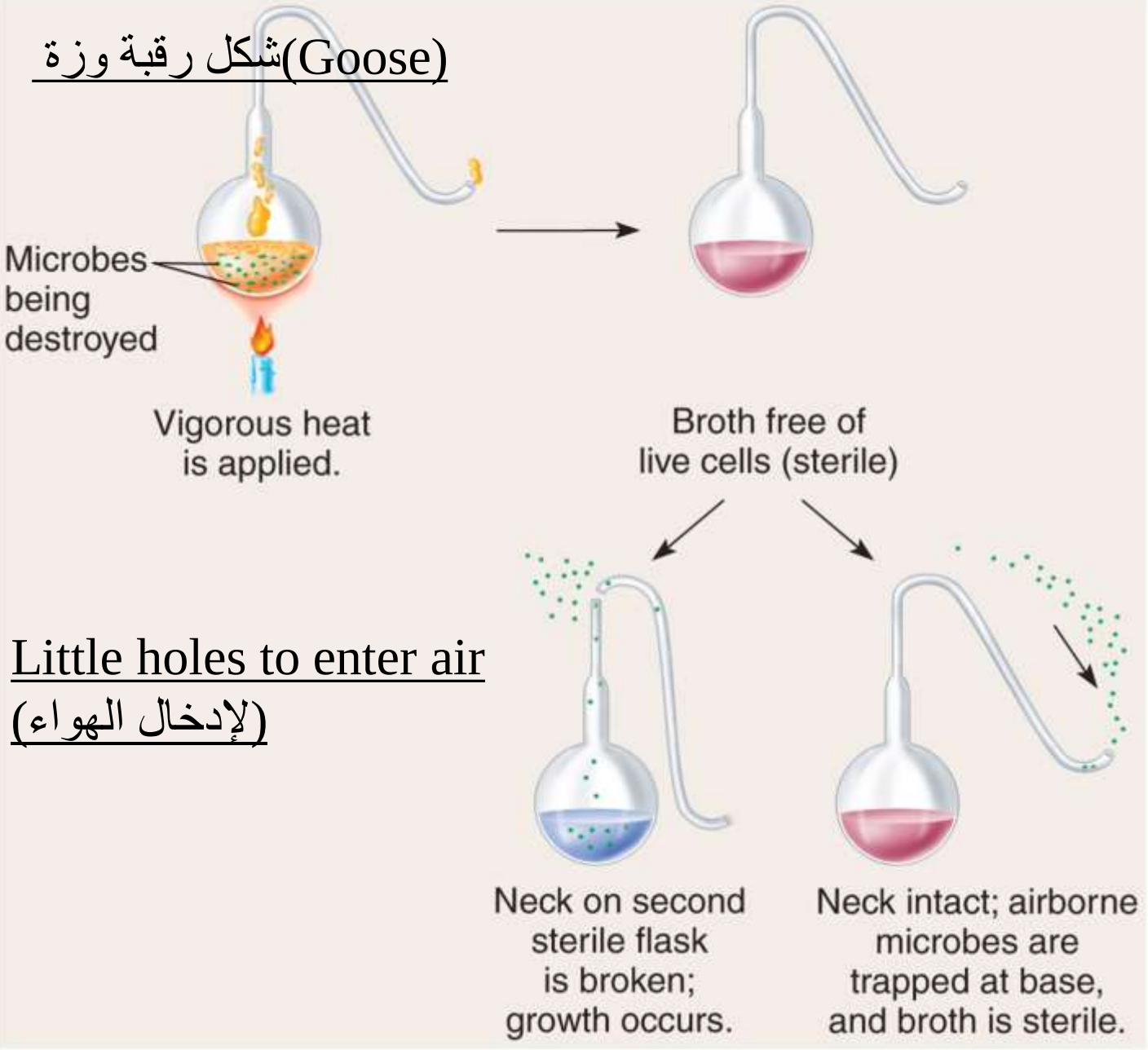
    mutton broth in flasks → boiled →sealed
  - results: broth became cloudy and contained microorganisms
- Lazzaro Spallanzani (1729-1799)
  - his experiment:

    broth in flasks →sealed → boiled
  - results: no growth of microorganisms

Louis Pasteur (1822-1895)(مهم جداً)

- 'Swan-neck flask' experiments
  - placed nutrient solution in flasks
  - created flasks with long, curved necks
  - boiled the solutions
  - left flasks exposed to air
- results: no growth of microorganisms

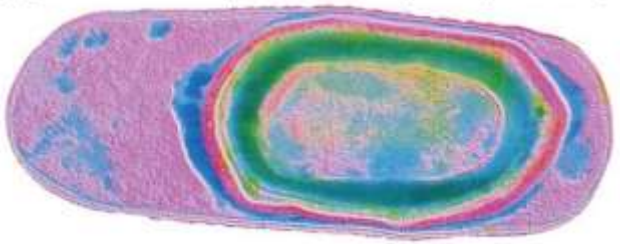
شكل رقبة وزة(Goose)



Little holes to enter air
(لإدخال الهواء)

Final Blow(ضربة قاضية) to Theory of Spontaneous Generation

- John Tyndall (1820-1893)
  - demonstrated that dust carries microorganisms
  - showed that if dust was absent, nutrient broths remained sterile(مُعقم), even if directly exposed to air
  - also provided evidence for the existence(وجود) of exceptionally heat-resistant forms of bacteria
- Ferdinand Cohn (1828-1898)
  - heat-resistant bacteria could produce endospores(الأبواغ)



Endospores(بوغ داخلي)

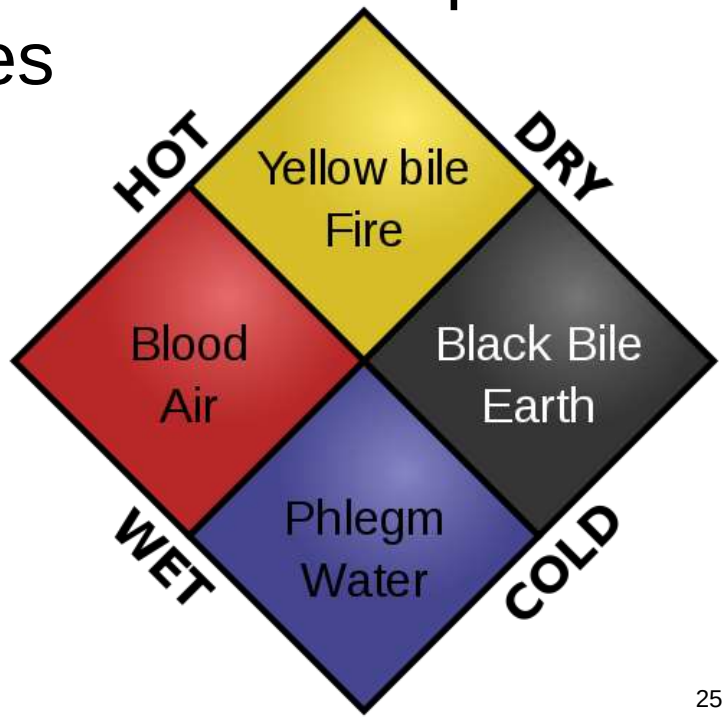
- **الأبواغ الداخلية** أو **التحوصل**:هو أن تقوم الأوليات بإحاطة نفسها بغلاف سميك مكونة ما يسمى بالحوصلة وذلك في الظروف غير الملائمة مثل:

- نقص الغذاء .نقص الرطوبة .نقص الأكسجين .عدم ملائمة درجة الحرارة .وجود مواد كيميائية سامة لها.

- أهمية الحوصلة:تعطي الحوصلة فترة زمنية أطول للكائن للبقاء حيا وتساعده على العيش خارج جسم العائل الذي تتطفل عليه حتى تسمح لها الظروف بالعودة إلى جسم العائل فتخرج من الحوصلة.

The Role of Microorganisms in Disease

- Was *not* immediately obvious
- Infectious disease believed to be due to supernatural forces or imbalances of 4 bodily-fluid ‘humors’(المزاجات)(الدم/البلغم/الصفراء/أسود الصفراوية صفراء)
- Establishing connection depended on development of techniques for studying microbes



Evidence for the Relationship between Microorganisms and Disease

- Agostini Bassi (1773-1856)
  - showed that a disease of silkworms was caused by a fungus
- M. J. Berkeley (ca. 1845)
  - demonstrated that the great Potato Blight of Ireland was caused by a water mold
- Heinrich de Bary (1853)
  - showed that smut(تفحم) and rust(صدأ) fungi caused cereal crop diseases(أمراض محصول الحبوب)

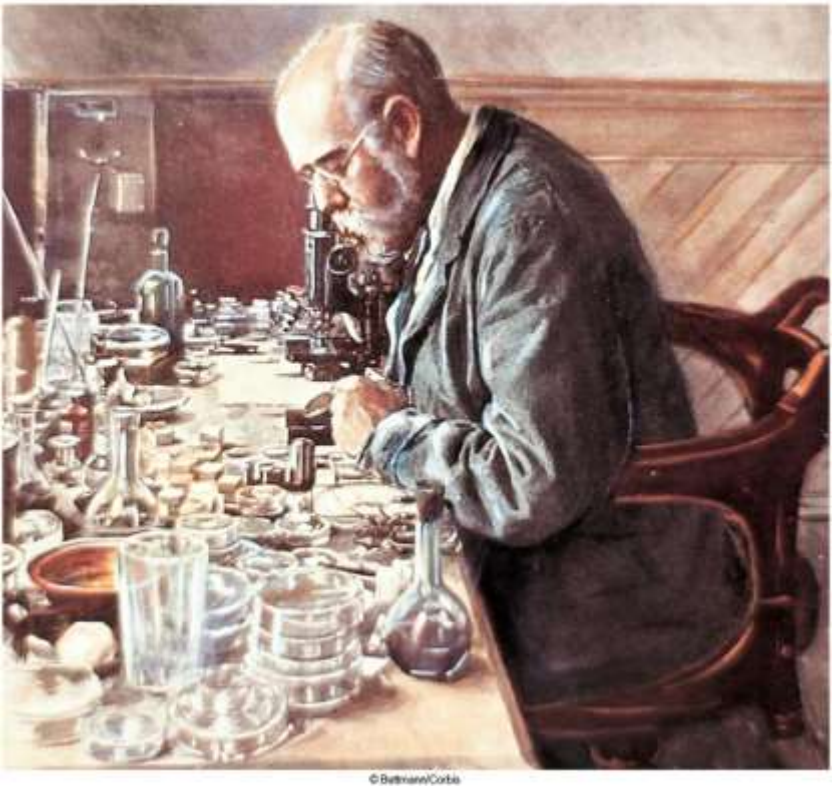
Other Evidence…

Joseph Lister

- provided indirect evidence that microorganisms were the causal agents(عوامل سببية) of disease
- developed a system of surgery designed to prevent microorganisms from entering wounds(الجروح) as well as methods for treating instruments and surgical dressings(الأدوات والضمادات الجراحية)
- his patients had fewer postoperative infections(التهابات ما بعد الجراحة)

Final Proof…

- Robert Koch (1843-1910)
  - established the relationship between *Bacillus anthracis* and anthrax(العصوية و الجمرة (العامل المسبب للجمرة الخبيثة)الجمرية الخبيثة)

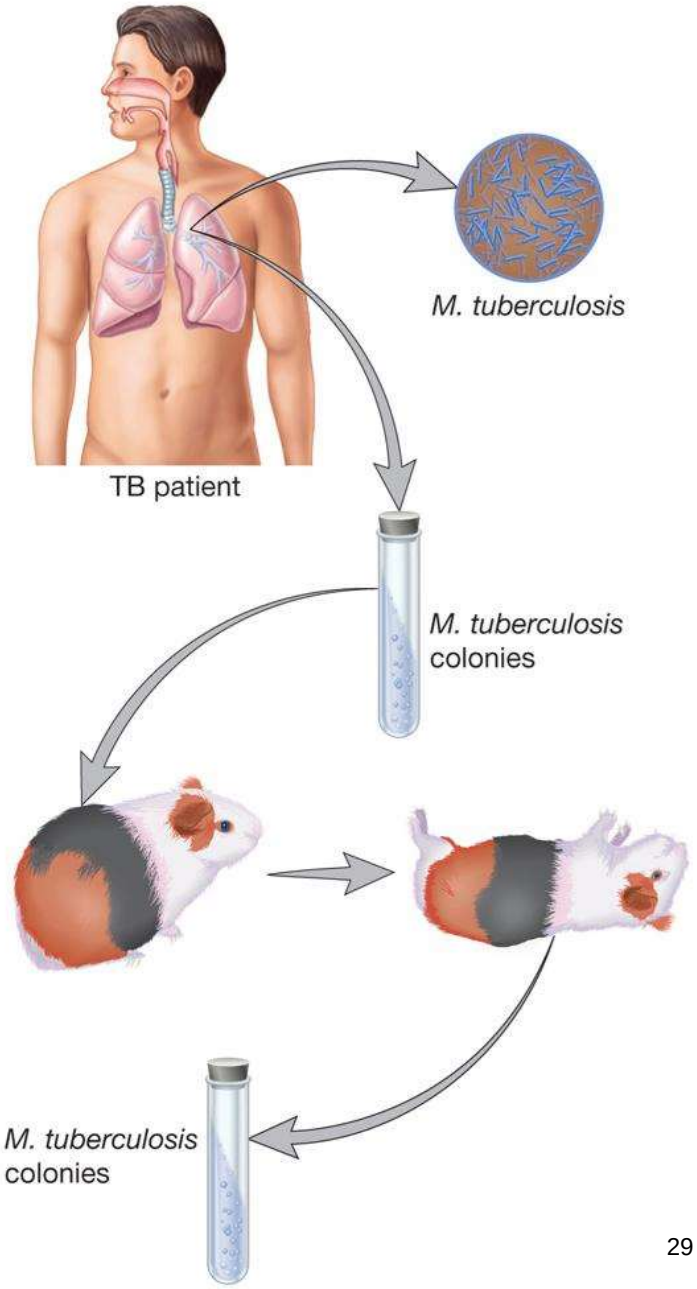


used criteria developed by his teacher Jacob Henle (1809-1895)

these criteria now known as Koch's postulates

- still used today to establish the link between a particular microorganism and a particular disease

Postulate	Experimentation
1. The microorganism must be present in every case of the disease but absent from healthy organisms.	Koch developed a staining technique to examine human tissue. *Mycobacterium tuberculosis* could be identified in diseased tissue.
2. The suspected microorganisms must be isolated and grown in a pure culture.	Koch grew *M. tuberculosis* in pure culture on coagulated blood serum.
3. The same disease must result when the isolated microorganism is inoculated into a healthy host.	Koch injected cells from the pure culture of *M. tuberculosis* into guinea pigs. The guinea pigs subsequently died of tuberculosis.
4. The same microorganisms must be isolated again from the diseased host.	Koch isolated *M. tuberculosis* in pure culture on coagulated blood serum from the dead guinea pigs.



Limitations of Koch's Postulates

- Some organisms cannot be grown in pure culture
- Using humans in completing the postulates is unethical
- Molecular and genetic evidence may replace and overcome these limits

The Development of Techniques for Studying Microbial Pathogens

- Koch's work led to discovery or development of:
  - agar
  - Petri dishes
  - nutrient broth and nutrient agar
  - methods for isolating microorganisms

Other Developments…

- Charles Chamberland (1851-1908)
  - developed porcelain(الخزف) bacterial filters used by Ivanoski and Beijerinck to study tobacco mosaic disease(مرض تبرقش التبغ)
    - determined that extracts from diseased plants had infectious agents present which were smaller than bacteria and passed through the filters
    - infectious agents were eventually shown to be viruses

Other Developments…

- Pasteur and Roux
  - discovered that incubation(حضانة) of cultures for long intervals between transfers caused pathogens to lose their ability to cause disease (termed ‘attenuation(تخفيف)’)
- Pasteur and his coworkers
  - developed vaccines(لقاحات) for chicken cholera(الكوليرا), anthrax, and rabies(داء الكلب)

Immunological Studies(الدراسات المناعية)

- once established, led to study of host defenses - immunology
- Edward Jenner (ca. 1798)
  - used a vaccination procedure to protect individuals from smallpox

    NOTE: this preceded the work establishing the role of microorganisms in disease!

More Developments…

- Emil von Behring (1854-1917) and Shibasaburo Kitasato (1852-1931)
  - developed antitoxins(مضادات السموم) for diphtheria(خناق) and tetanus(كزاز)
  - evidence for humoral (antibody-based) immunity
- Elie Metchnikoff (1845-1916)
  - discovered bacteria-engulfing, phagocytic cells(خلايا آكلة) in the blood
  - evidence for cellular immunity

The Development of Industrial Microbiology and Microbial Ecology

- Louis Pasteur
  - demonstrated that alcohol fermentations(تخمير) and other fermentations were the result of microbial activity
  - developed the process of pasteurization(بسترة) to preserve(للحفاظ على) wine during storage

Developments in Microbial Ecology

- Sergei Winogradsky (1856-1953) and Martinus Beijerinck (1851-1931)
  - studied soil microorganisms and discovered numerous interesting metabolic processes (e.g., nitrogen fixation)
  - Pioneered(رائدة) the use of enrichment(مخصبة) cultures and selective media

Microbiology Has Basic and Applied Aspects

- Basic aspects are concerned with individual groups of microbes, microbial physiology, genetics, molecular biology and taxonomy
- Applied aspects are concerned with practical problems – disease, water, food and industrial microbiology

Molecular and Genomic Methods

- Led to a second golden age of microbiology (rapid expansion of knowledge)
- Discoveries
  - restriction endonucleases (Arber and Smith)
  - first novel recombinant molecule (Jackson, Symons, Berg)
  - DNA sequencing methods (Woese, Sanger)
  - bioinformatics and genomic sequencing and analysis

Major Fields in Microbiology

- Medical microbiology – diseases of humans and animals
- Public health microbiology – control and spread of communicable diseases(الأمراض المعدية)
- Immunology(علم المناعة) – how the immune system protects a host from pathogens(مسببات الأمراض)

More Fields…

- Microbial ecology is concerned with(مهتمة بِـ) the relationship of organisms with their environment
  - less than 1% of earth's microbial population has been cultured
- Agricultural(الزراعية) microbiology is concerned with the impact of microorganisms on agriculture
  - food safety microbiology
  - animal and plant pathogens

More Fields….

- Industrial microbiology began in the 1800s
  - fermentation(تخمير)
  - antibiotic production(انتاج المضادات الحيوية)
  - production of cheese, bread, etc.
- Microbial physiology studies metabolic pathways of microorganisms

More Fields….

- Molecular biology, microbial genetics, and bioinformatics study the nature of genetic information and how it regulates the development and function of cells and organisms
- Microbes are a model system of genomics