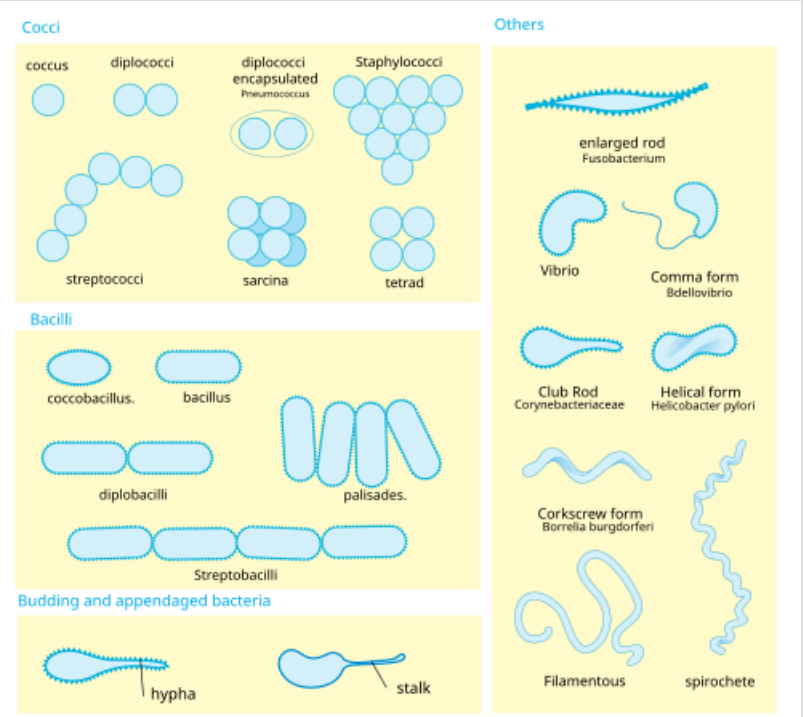
Bacterial cellular morphologies

Bacterial cellular morphologies are the shapes that are characteristic of various types of bacteria and often key to their identification. Their direct examination under a light microscope enables the classification of these bacteria (and archaea).

Generally, the basic morphologies are spheres (coccus) and round-ended cylinders or rod shaped (bacillus). But, there are also other morphologies such as helically twisted cylinders (example *Spirochetes*), cylinders curved in one plane (selenomonads) and unusual morphologies (the square, flat box-shaped cells of the Archaean genus *Haloquadratum)*. Other arrangements include pairs, tetrads, clusters, chains and palisades.

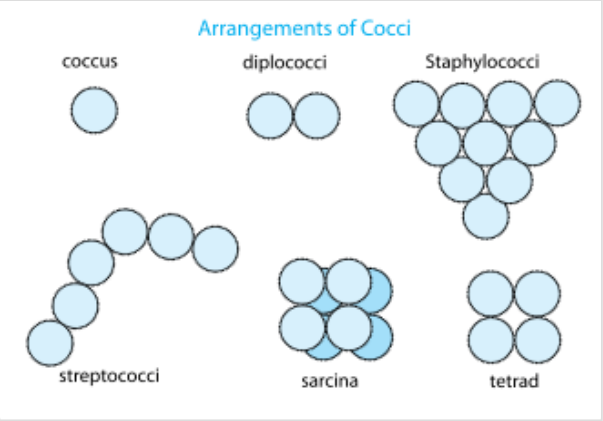


Bacteria display a large diversity of cell morphologies and arrangements.

Types

Coccus

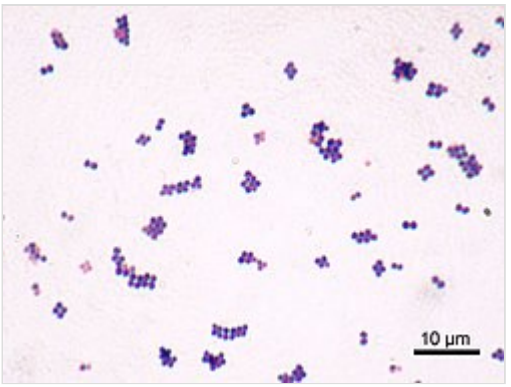
A **coccus** (plural *cocci*, from the Latin *coccinus* (scarlet) and derived from the Greek *kokkos* (berry)), is any microorganism (usually bacteria)[1] whose overall shape is spherical or nearly spherical.[2][3][4] Coccus refers to the shape of the bacteria and can contain multiple genera, such as staphylococci or streptococci. Cocci can grow in pairs, chains, or clusters, depending on their orientation and attachment during cell division. In contrast to many bacilli-shaped bacteria, most cocci bacteria do not have flagella and are non-motile.[5]



Arrangement of cocci bacteria

Cocci is an English loanword of a modern or Neo-Latin noun, which in turn stems from the Greek masculine noun κόκκος (*cóccos*) meaning 'berry'.[6]

Important human diseases caused by coccoid bacteria include staphylococcal infections, some types of food poisoning, some urinary tract infections, toxic shock syndrome, gonorrhea, as well as some forms of meningitis, throat infections, pneumonias, and sinusitis.[7]



Staphylococcus bacteria

Arrangements

Coccoid bacteria often occur in characteristic arrangements and these forms have specific names as well;[8] listed here are the basic forms as well as representative bacterial genera:[3]

- Diplococci are pairs of cocci.
- **Streptococci** are chains of cocci such as *Streptococcus pyogenes*.
- **Staphylococci** are irregular (grape-like) clusters of cocci (e.g. *Staphylococcus aureus*).
- **Tetrads** are clusters of four cocci arranged within the same plane such as *Micrococcus sp.*).
- **Sarcina** describes a pack-like cuboidal arrangement of eight cocci such as *Sarcina ventriculi*.

Gram-positive cocci

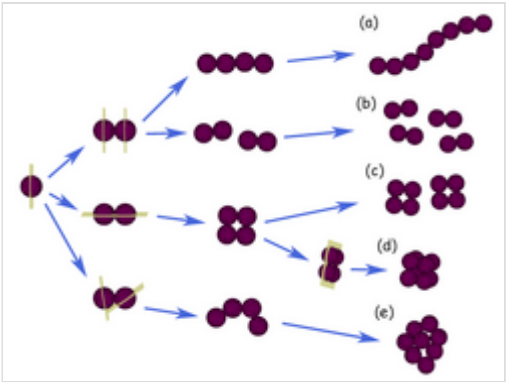
The gram-positive cocci are a large group of bacteria with similar morphology. All are spherical or nearly so, but they vary considerably in size. Members of some genera are identifiable by the way cells are attached to one another: in pockets, in chains, or grape-like clusters. These arrangements reflect patterns of cell division and that cells stick together. *Sarcina* cells, for example, are arranged in cubical pockets because cell division alternates regularly among the three perpendicular planes. *Streptococcus* spp. resemble a string of beads because division always occurs in the same plane. Some of these strings, for example, *S. pneumoniae*, are only two cells long. They are called *diplococci.* Species of *Staphylococcus* have no regular plane of division. They form grape-like structures.[9]

The various gram-positive cocci differ physiologically and by habitat. *Micrococcus* spp. are obligate aerobes that inhabit human skin. *Staphylococcus* spp. also inhabit human skin, but they are facultative anaerobes. They ferment sugars, producing lactic acid as an end product. Many of these species produce carotenoid pigments, which color their colonies yellow or orange. *Staphylococcus aureus* is a major human pathogen. It can infect almost any tissue in the body, frequently the skin. It often causes nosocomial (hospital-acquired) infections.[9]

Diplococci

Diplococci are pairs of cocci. Examples of gram-negative diplococci are *Neisseria* spp. and *Moraxella catarrhalis*. Examples of gram-positive diplococci are *Streptococcus pneumoniae* and *Enterococcus* spp.[10][11] Presumably, diplococcus has been implicated in encephalitis lethargica.[12] The genus *Neisseria* belongs to the family Neisseriaceae. This genus, *Neisseria*, is divided into more than ten different species, but most of them are gram negative and coccoid. The gram-negative, coccoid species include: *Neisseria cinerea*, *N. gonorrhoeae*, *N. polysaccharea*, *N. lactamica*, *N. meningitidis*, *N. mucosa*, *N. oralis* and *N. subflava*. The most common of these species are the pathogenic *N. meningitidis* and *N. gonorrhoeae*.[13]

The genus *Moraxella* belongs to the family *Moraxellaceae*. This genus, *Moraxellaceae*, comprises gram-negative coccobacilli bacteria: *Moraxella lacunata*, *M. atlantae*, *M. boevrei*, *M. bovis*, *M. canis*, *M. caprae*, *M. caviae*, *M. cuniculi*, *M. equi*, *M. lincolnii*, *M. nonliquefaciens*, *M. osloensis*, *M. ovis*, *M. saccharolytica*, and *M. pluranimalium*.[14] However, only one has a morphology of diplococcus, *M. catarrhalis*, a salient pathogen contributing to infections in the human body.[15]



Structure b represents diplococcus bacteria

The species *Streptococcus pneumoniae* belongs to the genus *Streptococcus* and the family *Streptococcaceae*. The genus *Streptococcus* has around 129 species and 23 subspecies[16] that benefit many microbiomes on the human body. There are many species that show non-pathogenic characteristics; however, there are some, like *S. pneumoniae*, that exhibit pathogenic characteristics in the human body.[17][11]

The genus *Enterococcus* belongs to the family *Enterococcaceae*. This genus is divided into 58 species and two subspecies.[18] These gram-positive, coccoid bacteria were once thought to be harmless to the human body. However, within the last ten years, there has been an influx of nosocomial pathogens originating from *Enterococcus* bacteria.[19][11]

Bacillus

A **bacillus** (pl.: **bacilli**), also called a **bacilliform bacterium** or often just a **rod** (when the context makes the sense clear), is a rod-shaped bacterium or archaeon. Bacilli are found in many different taxonomic groups of bacteria. However, the name *Bacillus*, capitalized and italicized, refers to a specific genus of bacteria. The name Bacilli, capitalized but not italicized, can also refer to a less specific taxonomic group of bacteria that includes two orders, one of which contains the genus *Bacillus*. When the word is formatted with lowercase and not italicized, 'bacillus', it will most likely be referring to shape and not to the genus. Bacilliform bacteria are also often simply called rods when the bacteriologic context is clear.[20]

Bacilli usually divide in the same plane and are solitary, but can combine to form diplobacilli, streptobacilli, and palisades.[21]

- Diplobacilli: Two bacilli arranged side by side with each other.
- Streptobacilli: Bacilli arranged in chains.
- Coccobacillus: Oval and similar to coccus (circular shaped bacterium).[22]

There is no connection between the shape of a bacterium and its color upon Gram staining; there are both gram-positive rods and gram-negative rods. MacConkey agar can be used to distinguish among gram-negative bacilli such as *E. coli* and salmonella.[23]

Arrangements

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- Diplobacilli: Two bacilli arranged side by side with each other.
- Streptobacilli: Bacilli arranged in chains.[2][1]

Gram-positive examples

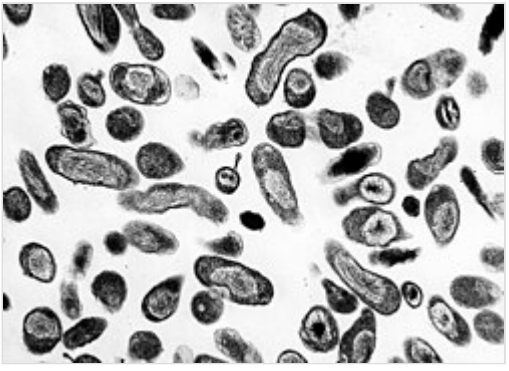
- *Actinomyces*
- *Bacillus*
- *Clostridium*
- *Corynebacterium*
- *Listeria*
- *Propionibacterium*

Gram-negative examples

- *Bacteroides*
- *Citrobacter*
- *Enterobacter*
- *Escherichia*
- *Klebsiella*
- *Pseudomonas*
- *Proteus*
- *Salmonella*
- *Serratia*
- *Shigella*
- *Vibrio*
- *Yersinia*

Coccobacillus

A **coccobacillus** (plural **coccobacilli**), or **bacillococcus**, is a type of bacterium with a shape intermediate between cocci (spherical bacteria) and bacilli (rod-shaped bacteria). Coccobacilli, then, are very short rods which may be mistaken for cocci.[25] The word *coccobacillus* reflects an intermediate shape between *coccus* (spherical) and *bacillus* (elongated).[2]



Coxiella burnetii (TEM)

Haemophilus influenzae, *Gardnerella vaginalis*, and *Chlamydia trachomatis* are coccobacilli. *Aggregatibacter actinomycetemcomitans* is a Gram-negative coccobacillus prevalent in subgingival plaques. *Acinetobacter* strains may grow on solid media as coccobacilli. *Bordetella pertussis* is a Gram-negative coccobacillus responsible for causing whooping cough. *Yersinia pestis*, the bacterium that causes plague, is also a coccobacillus.[26]

Coxiella burnetii is also a coccobacillus.[27][28] Bacteria from the genus *Brucella* are medically important coccobacilli that cause brucellosis. *Haemophilus ducreyi*, another medically important Gram-negative coccobacillus, is observed in sexually transmitted disease, chancroid, of Third World countries.[29]

Spiral

Spiral bacteria are another major bacterial cell morphology.[2][30][31][32] Spiral bacteria can be sub-classified as spirilla, spirochetes, or vibrios based on the number of twists per cell, cell thickness, cell flexibility, and motility.[33]

Bacteria are known to evolve specific traits to survive in their ideal environment.[34] Bacteria-caused illnesses hinge on the bacteria's physiology and their ability to interact with their environment, including the ability to shapeshift. Researchers discovered a protein that allows the bacterium *Vibrio cholerae* to morph into a corkscrew shape that likely helps it twist into — and then escape — the protective mucus that lines the inside of the gut.[34]

Spirillum

A spirillum (plural spirilla) is a rigid spiral bacterium that is gram-negative and frequently has external amphitrichous or lophotrichous flagella.[33] Examples include:

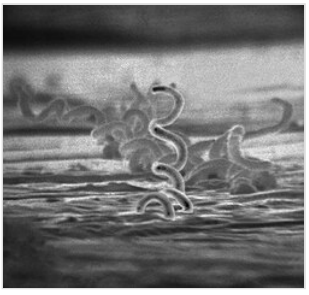
- Members of the genus *Spirillum*
- *Campylobacter* species, such as *Campylobacter jejuni*, a foodborne pathogen that causes campylobacteriosis
- *Helicobacter* species, such as *Helicobacter pylori*, a cause of peptic ulcers

Campylobacter jejuni is a common pathogen of bacterial food-related gastrointestinal illness.

Spirochetes

A spirochete (plural spirochetes) is a very thin, elongate, flexible, spiral bacteria that is motile via internal periplasmic flagella inside the outer membrane.[33] They comprise the phylum Spirochaetes. Owing to their morphological properties, spirochetes are difficult to Gram-stain but may be visualized using dark field microscopy or Warthin–Starry stain.[35] Examples include:

- *Leptospira* species, which cause leptospirosis.
- *Borrelia* species, such as *Borrelia burgdorferi*, a tick-borne bacterium that causes Lyme disease
- *Treponema* species, such as *Treponema pallidum*, subspecies of which causes treponematoses, including syphilis



Thin spirochete *Treponema pallidum* bacteria, the causative agent of syphilis magnified 400 times.

Helical

Helicobacter species are helically shaped, the most common example of which is *Helicobacter pylori*.[36] A helical shape is seen to be better suited for movement of bacteria in a viscous medium.[37]

See also

- Bacterial morphological plasticity
- Ferdinand Cohn – gave first named shapes of bacteria

References

1. Cole JR (January 1990). "Diagnostic Procedure in Veterinary Bacteriology and Mycology". In Carter GR, Cole JR (eds.). *17 - Streptococcus and Related Cocci* (Fifth ed.). San Diego: Academic Press. pp. 211–220. doi:10.1016/b978-0-12-161775-2.50021-9 (https://doi.org/10.1016%2Fb978-0-12-161775-2.50021-9). ISBN 978-0-12-161775-2.
2. Zapun A, Vernet T, Pinho MG (March 2008). "The different shapes of cocci" (https://doi.org/10.1111%2Fj.1574-6976.2007.00098.x). *FEMS Microbiology Reviews*. **32** (2): 345–360. doi:10.1111/j.1574-6976.2007.00098.x (https://doi.org/10.1111%2Fj.1574-6976.2007.00098.x). PMID 18266741 (https://pubmed.ncbi.nlm.nih.gov/18266741).
3. Pommerville, J.C. (2013). *Fundamentals of Microbiology* (10th ed.). Sudbury, MA: Jones & Bartlett. p. 106. ISBN 978-1-4496-4796-4.
4. Ryan, Kenneth James (4 January 2018). *Sherris medical microbiology* (7th ed.). New York: McGraw-Hill Education. ISBN 978-1-259-85980-9. OCLC 983825627 (https://search.worldcat.org/oclc/983825627).
5. Levinson, Warren; Joyce, Elizabeth A.; Nussbaum, Jesse; Schwartz, Brian S.; Chin-Hong, Peter (10 May 2018). *Review of medical microbiology & immunology: a guide to clinical infectious diseases* (15th ed.). New York: McGraw-Hill Education. ISBN 978-1-259-64449-8. OCLC 1032261353 (https://search.worldcat.org/oclc/1032261353).
6. κόκκος (https://www.perseus.tufts.edu/hopper/text?doc=Perseus:text:1999.04.0057:entry=ko/kkos). Liddell, Henry George; Scott, Robert; *A Greek–English Lexicon* at the Perseus Project
7. Ryan KJ, Ray CG, eds. (2004). *Sherris Medical Microbiology* (4th ed.). McGraw Hill. ISBN 0-8385-8529-9.
8. Salton MR, Kim KS (1996). Baron S, et al. (eds.). *Structure.* In: *Baron's Medical Microbiology* (4th ed.). Univ of Texas Medical Branch. ISBN 0-9631172-1-1. (via NCBI Bookshelf) (https://www.ncbi.nlm.nih.gov/books/NBK8477/).
9. Ingraham, Catherine A.; Ingraham, John L. (2000). *Introduction to Microbiology* (https://archive.org/details/introductiontomi0000ingr).
10. Richard A. Harvey (Ph.D.) (2007). *Microbiology* (https://books.google.com/books?id=FPd38Gc33gwC&pg=PA395). Lippincott Williams & Wilkins. pp. 395–. ISBN 978-0-7817-8215-9.
11. Gillespie, Claire (August 20, 2018). "Types of Coccus Bacteria" (https://sciencing.com/types-coccus-bacteria-8511915.html). *Sciencing*. Retrieved 2019-12-01.
12. "Mystery of the forgotten plague" (https://news.bbc.co.uk/2/hi/health/3930727.stm). 2004-07-27.
13. "Neisseria Trevisan, 1885" (https://www.gbif.org/species/3220214). *www.gbif.org*. Retrieved 2019-12-02.
14. "Moraxella" (https://lpsn.dsmz.de/species/moraxella-catarrhalis). *LPSN*. Retrieved 2019-12-02.
15. Verhaegh, S.J.C. (Suzanne) (2011-06-01). *Epidemiology and pathogenesis of Moraxella catarrhalis colonization and infection*. Lippincott Williams & Wilkins. ISBN 978-0-397-51568-4. OCLC 929980928 (https://search.worldcat.org/oclc/929980928).
16. "Streptococcus" (https://lpsn.dsmz.de/genus/streptococcus). *LPSN*. Retrieved 2019-12-02.
17. "Streptococcus pneumoniae (Klein, 1884) Chester, 1901" (https://web.archive.org/web/20200401122032/https://www.gbif.org/species/111218319). *www.gbif.org*. Archived from the original (https://www.gbif.org/species/111218319) on 2020-04-01. Retrieved 2019-12-02.
18. "Enterococcus" (https://lpsn.dsmz.de/genus/enterococcus). *LPSN*. Retrieved 2019-12-02.

19. Fisher, Katie; Phillips, Carol (2009). "The ecology, epidemiology and virulence of Enterococcus" (https://doi.org/10.1099%2Fmic.0.026385-0). *Microbiology*. **155** (6): 1749–1757. doi:10.1099/mic.0.026385-0 (https://doi.org/10.1099%2Fmic.0.026385-0). ISSN 1350-0872 (https://search.worldcat.org/issn/1350-0872). PMID 19383684 (https://pubmed.ncbi.nlm.nih.gov/19383684).
20. "The Size, Shape, And Arrangement Of Bacterial Cells" (https://web.archive.org/web/20160809135552/http://classes.midlandstech.edu/carterp/courses/bio225/chap04/lecture2.htm). Midlands Technical College. Archived from the original (http://classes.midlandstech.edu/carterp/courses/bio225/chap04/lecture2.htm) on 9 August 2016. Retrieved 8 August 2016.
21. "Chapter 4: Functional Anatomy Of Prokaryotic And Eukaryotic Cells" (https://web.archive.org/web/20120923190032/http://www2.nemcc.edu/bkirk/Template%201/MICROCHAPTER4NOTES.htm). Archived from the original (http://www2.nemcc.edu/bkirk/Template%201/MICROCHAPTER4NOTES.htm) on 23 September 2012.
22. Kaiser GE. "Sizes, Shapes, and Arrangements of Bacteria" (https://web.archive.org/web/20190811021638/http://faculty.ccbcmd.edu/courses/bio141/lecguide/unit1/shape/shape.html). The Community College of Baltimore County. Archived from the original (http://faculty.ccbcmd.edu/courses/bio141/lecguide/unit1/shape/shape.html) on 11 August 2019. Retrieved 8 August 2016.
23. "Gram Negative Bacilli" (https://web.archive.org/web/20090314013352/http://education.med.nyu.edu/courses/old/microbiology/courseware/infect-disease/Gram_Neg_Bacilli5.html). NYU School of Medicine. Archived from the original (http://education.med.nyu.edu/courses/old/microbiology/courseware/infect-disease/Gram_Neg_Byacilli5.html) on 14 March 2009.
24. Harry E, Monahan L, Thompson L (2006). *Bacterial cell division: the mechanism and its precision*. International Review of Cytology. Vol. 253. pp. 27–94. doi:10.1016/S0074-7696(06)53002-5 (https://doi.org/10.1016%2FS0074-7696%2806%2953002-5). ISBN 978-0-12-373597-3. PMID 17098054 (https://pubmed.ncbi.nlm.nih.gov/17098054).
25. Tankeshwar, Acharya (April 11, 2016). "Gram-Negative Cocci and Coccobacilli of Medical Significance; List of Bacteria and Diseases" (https://microbeonline.com/gram-negative-cocci-coccobacilli-medical-significance-list-bacteria-diseases/).
26. Collins, Frank M. (1996). "Pasteurella, Yersinia, and Francisella" (https://www.ncbi.nlm.nih.gov/books/NBK7798/). In Baron, Samuel (ed.). *Medical Microbiology* (https://www.ncbi.nlm.nih.gov/books/NBK7627/) (4th ed.). University of Texas Medical Branch at Galveston. ISBN 978-0-9631172-1-2. PMID 21413268 (https://pubmed.ncbi.nlm.nih.gov/21413268).
27. McCaul TF, Williams JC (September 1981). "Developmental cycle of Coxiella burnetii: structure and morphogenesis of vegetative and sporogenic differentiations" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC216147). *Journal of Bacteriology*. **147** (3): 1063–1076. doi:10.1128/jb.147.3.1063-1076.1981 (https://doi.org/10.1128%2Fjb.147.3.1063-1076.1981). PMC 216147 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC216147). PMID 7275931 (https://pubmed.ncbi.nlm.nih.gov/7275931).
28. Walters, Sherry (Spring 2004). Thacker, Leon (ed.). "Q-fever (Coxiella burnetti) Zoonoses: An historical and persistent rickettsial disease" (http://www.addl.purdue.edu/newsletters/2004/spring/qfever.htm). *Purdue University Animal Disease Diagnostic Laboratory*. Retrieved 22 September 2025.
29. Schaechter, Moselio; DiRita, Victor J.; Dermody, Terence (2007). Schaechter, Moselio; Engleberg, N. Cary (eds.). *Schaechter's Mechanisms of Microbial Disease* (https://books.google.com/books?id=1Zl70SLDU3oC) (4 ed.). Philadelphia, Pa.: Lippincott Williams & Wilkins. p. 666. ISBN 978-0-7817-5342-5.
30. Young KD (September 2006). "The selective value of bacterial shape" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1594593). *Microbiology and Molecular Biology Reviews*. **70** (3): 660–703. doi:10.1128/MMBR.00001-06 (https://doi.org/10.1128%2FMMBR.00001-06). PMC 1594593 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1594593). PMID 16959965 (https://pubmed.ncbi.nlm.nih.gov/16959965).

31. Csuros, Maria; Csuros, Csaba (1999). *Microbiological Examination of Water and Wastewater*. Boca Raton, Florida: CRC Press. pp. 16–17. ISBN 978-1-56670-179-2.
32. Young, Kevin D. (September 2006). "The Selective Value of Bacterial Shape" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1594593). *Microbiology and Molecular Biology Reviews*. **70** (3): 660–703. doi:10.1128/MMBR.00001-06 (https://doi.org/10.1128%2FMMBR.00001-06). PMC 1594593 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1594593). PMID 16959965 (https://pubmed.ncbi.nlm.nih.gov/16959965).
33. Talaro, Kathleen (2007). *Foundations in Microbiology* (https://books.google.com/books?id=4hhgYEJZfisC&q=spirillum%20and%20spirochete&pg=PA108) (6th International ed.). McGraw-Hill. pp. 108–109. ISBN 978-0-07-126232-3. Retrieved 11 September 2017.
34. Tan YS, Zhang RK, Liu ZH, Li BZ, Yuan YJ (2022). "Microbial Adaptation to Enhance Stress Tolerance" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9093737). *Frontiers in Microbiology*. **13** 888746. doi:10.3389/fmicb.2022.888746 (https://doi.org/10.3389%2Ffmicb.2022.888746). PMC 9093737 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9093737). PMID 35572687 (https://pubmed.ncbi.nlm.nih.gov/35572687).
35. Humphrey, Peter A.; Dehner, Louis P.; Pfeifer, John D., eds. (2008). "Chapter 53: Histology and histochemical stains". *The Washington Manual of Surgical Pathology*. Philadelphia: Lippincott Williams & Wilkins. p. 680. ISBN 978-0-7817-6527-5.
36. Constantino MA, Jabbarzadeh M, Fu HC, Bansil R (November 2016). "Helical and rod-shaped bacteria swim in helical trajectories with little additional propulsion from helical shape" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5262464). *Sci Adv*. **2** (11) e1601661. doi:10.1126/sciadv.1601661 (https://doi.org/10.1126%2Fsciadv.1601661). PMC 5262464 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5262464). PMID 28138539 (https://pubmed.ncbi.nlm.nih.gov/28138539).
37. Young KD (September 2006). "The selective value of bacterial shape" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1594593). *Microbiol Mol Biol Rev*. **70** (3): 660–703. doi:10.1128/MMBR.00001-06 (https://doi.org/10.1128%2FMMBR.00001-06). PMC 1594593 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1594593). PMID 16959965 (https://pubmed.ncbi.nlm.nih.gov/16959965).

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- Bacteria Picture Gallery (http://www.bacteria-world.com/bacteria-pictures.htm)