Meaning of gram positive and gram negative bacteria

In formal descriptions of the germ-fighting powers of antibacterial and biocidal products, the terms "Gram positive" and "Gram negative" are used as a way to categorize bacteria. While there are estimated to be over 10,000 species of bacteria, they can be categorized into a few helpful categories. One of those categories has to do with the structure of the cell membrane. All the known bacteria fit into one of two categories of cell membrane structure: Gram-positive or Gram-negative. But what does that mean? Let's first look at where "Gram" comes from. In this case, Gram - with a capital G - refers to the Danish bacteriologist Hans Christian Gram. In 1884, Gram devised a test to identify whether or not a bacteria had a peptidoglycan (a mesh-like layer of sugars and amino acids) wall. In his test, a dye was introduced to the bacteria. If the bacteria had a thick peptidoglycan cell wall, it absorbed the dye and turned purple - it tested positive for peptidoglycan. If it did not turn purple, it tested negative for peptidoglycan, meaning, its peptidoglycan layer was thin. As this method was adopted, the resulting categories were called "Gram positive" and "Gram negative." This method of "Gram staining" is still a widely-used, standard procedure in microbiology. Now we can look at some of the most important differences between Gram-positive and Gram-negative bacteria in the fight against HAIs. The reason EPA public health claims, and as a result, products, clarify that testing includes both Gram-positive and Gram-negative bacteria is that they have different levels of resistance to cleansing products, different reactions to dry surfaces, and other important distinctions. Gram-positive bacteria, those species with peptidoglycan outer layers, are easier to kill - their thick peptidoglycan layer absorbs antibiotics and cleaning products easily. In contrast, their many-membraned cousins resist this intrusion with their multi-layered structure. Therefore, infection prevention techniques must ensure that they can breach the thick peptidoglycan layer of the Gram-positive bacteria but also get through the many layers of the Gram-negative bacteria. However thin their peptidoglycan layer, Gram-negative bacteria are protected from certain physical assaults because they do not absorb foreign materials that surround it (including Gram's purple dye). Imagine a spacecraft with a series of airlocks. Any intruder would have to make their way through these airlocks before entering the ship. Such is the case with gram-negative bacteria. Their additional membrane allows them to control what reaches the inner airlock, enabling them to sequester or even remove threats in that space between the membranes (periplasmic space) before it reaches the cell itself. As a result, Gram-negative bacteria are not destroyed by certain detergents which easily kill Gram-positive bacteria. While thick, the Gram-positive bacteria's membrane absorbs foreign materials (Gram's dye), even those that prove toxic to its insides. This makes them easier to destroy with certain detergents. As a result, only certain cleansers are approved for use to eliminate bacteria - because it must kill both Gram-positive and Gram-negative bacteria. Gram-negative bacteria cannot survive as long as Gram-positive bacteria on dry surfaces (while both survive a surprisingly long time). This makes certain species more dangerous between routine cleaning, since they can survive and even multiply on dry surfaces. However, the long survival time of many pathogens means hospitals must use novel technologies to eradicate bacteria between routine cleanings. Finally, Gram-negative bacteria are more intrinsically resistant to antibiotics - they don't absorb the toxin into their insides. Their ability to resist traditional antibiotics make them more dangerous in hospital settings, where patients are weaker and bacteria are stronger. New and very expensive antibiotics have been developed to combat these resistant species, but there remain some superbugs (MDROs) that nothing can kill. Not only do the Gram-negative bacteria's natural defenses keep out these antibiotics, some even have an acquired resistance to antibiotics that make it to their inner cell bodies. Gram-positive and Gram-negative bacteria exist everywhere, but pose unique threats to hospitalized patients with weak immune systems. Gram-positive bacteria cause tremendous problems and are the focus of many eradication efforts, but meanwhile, Gram-negative bacteria have been developing dangerous resistance and are therefore classified by the CDC as a more serious threat. For this reason, the need for new technologies that kill bacteria, both Gram-positive and Gram-negative, are essential to make hospitals safer for everyone. Editor's Note: This post was originally published in August 2015 and has been updated for freshness, accuracy and comprehensiveness. Health and wellness professionals who understand the difference between Gram-positive and Gram-negative bacteria are better equipped to interpret and utilize high-quality essential oil and herbal medicine research. After all, one of the best ways to fight Gram-positive and Gram-negative bacterial outbreaks is to prevent them from occurring in the first place! Have you ever wondered what the difference is between Gram-positive and Gram-negative bacteria? Do these terms confuse you? Picture a bulletproof vest or a thin chain mail shirt worn by ancient soldiers. If you can do this, you can understand the natural health implications of Gram-negative bacteria. By comparison, have you ever seen a thick wooden fence surrounding a yard or a thick dry walled partition inside a house? If so, then you can understand the natural health implications of Gram-positive bacteria. The key to understanding these differences is in the protective membrane, or outer covering, surrounding these bacterial organisms. Gram-negative bacteria have a thin membrane, which is nearly "bulletproof." Gram-positive bacteria have a big, thick membrane. Image: Structure of Gram-positive cell wall. Image is copyright free from Wikimedia Commons at Gram-positive_cellwall-schematic.png What do natural health professionals need to know about Gram-negative bacteria? Gram-negative bacteria's cell membrane is thin but difficult to penetrate. Because of this nearly "bulletproof" membrane, they are often resistant to antibiotics and other antibacterial interventions. Examples of Gram-negative bacteria include cholera, gonorrhea, and Escherichia coli (E. coli). The protective covering of these, and other, Gram-negative bacteria make them much more difficult to heal and eradicate. {{cta('d905cbe0-ecbf-4e7b-ac58-5c650623e5bf')}} What do natural health professionals need to know about Gram-positive bacteria? The cell membrane of Gram-positive bacteria can be as much as 20-fold thicker than the protective covering of Gram-negative bacteria. Some examples of Gram-positive bacteria include Streptococcus, Staphylococcus, and Clostridium botulinum (botulism toxin). Gram-positive bacteria have a greater volume of peptidoglycan (a polymer of amino acids and sugars that create the cell wall of all bacteria in their cell membranes), which is what makes the thick outer covering. This thick outer covering, or membrane, is capable of absorbing a lot of foreign material. Image: Structure of gram-negative cell wall. Image copyright free from Wikimedia Commons at Gram_negative_cell_wall.svg How do Gram-negative and Gram-positive bacteria influence bacterial evolution and natural health? Remember, a bulletproof vest is very thin, while a heavy wood fence or a drywalled partition is quite thick. If someone used a common gun and shot a slug at the bulletproof vest, it would probably not penetrate or go through it. The bulletproof vest is difficult to penetrate with powerful weapons. Thus, in this analogy, our Gram-negative bacteria (the person wearing the bulletproof vest) would likely be unharmed. However, if someone shot a bullet at a thick wooden fence, or shot through a drywalled barrier in a room, the projectile would probably penetrate these surfaces and blast completely through. A damaging hole would be created in the drywall or wooden structure, Gram-positive bacteria in this analogy. Remember, too, that thick fences and drywall can absorb material such as sand, dirt, dust, paint, water, mold, etc. They can rot, crack, weaken, become mushy, and eventually peel away and become brittle. Comparatively, thin bulletproof vests do not easily absorb dirt, dust, sand, mold, or water. They do not rot or attract fungus. They also do not fracture, become schmaltzy, or break. Thus, the thick fence and house walls (Gram-positive bacteria) are capable of absorbing more matter, whereas the thin, protective martial barriers do not absorb stray particulates (Gram-negative bacteria). If you want to penetrate these surfaces, then you must employ different strategies. This is the same principle applied by pharmacologists, who use different drug tactics to pierce the membrane of dissimilar bacteria. Thus, with these analogies, you can quite easily see why some of the "big gun" antibiotics, which work well for serious infections like staph or strep, may have little effect on plaguing Gram-negative bacterium eruptions, such as a cholera outbreak or a mass gonorrheal epidemic. The fire-hose or shotgun-bullet antibiotics, which easily damage Gram-positive bacterial membranes, are often unable to blast through or weaken the protective coverings found on Gram-negative bacterium. Food for Thought Have you ever wondered about bacterial evolution and why certain antibiotics, which were once effective, suddenly become impotent and powerless? To understand this phenomenon, consider the example of fireproof drywall. Years ago, fire could easily burn down a room in a house. Today, fireproof chemicals in drywall have made it much more difficult for an intense heat blast to weaken these fortifications. Likewise, mold-resistant fence wood and water-resistant bathroom drywall have made it much more difficult for these structures to be damaged by rot, moisture, and mildew. Drywall, fences, and insulation have evolved to withstand certain forces that were previously damaging. Moreover, there are even bulletproof walls and lead-lined walls, which are designed to withstand the lethal force of guns, radiation, and bombs. Accordingly, bacteria have often evolved in a similar style. Bacterium with certain protective mutations often survive the onslaught of antibiotics, and then subsequently reproduce offspring with these same defensive characteristics. Thus, an individual or a population can experience an outbreak of super bacteria that are more "fireproof," "mold proof," and "bulletproof" to antibiotics. Therefore, there is a great need to educate people about the benefits of adopting a healthy, holistic lifestyle. A holistic health lifestyle can include modifications like consuming organic fruits and vegetables, choosing proper herbal and nutritional supplements, and regular exercise. These practices can increase the body's natural immunities and help people to resist illness without relying on antibiotics. One of the best ways to fight Gram-positive and Gram-negative bacterial outbreaks is to prevent them from occurring in the first place! Are you inspired to learn more about the structure and function of the human body, including natural immunity? Or maybe your goal is to take health and wellness courses so you can coach others about how to make smart lifestyle choices. ACHS has several accredited, online programs in holistic nutrition, wellness coaching, herbal medicine, aromatherapy, and more. Disclosure of Material Connection: All opinions are my own. This blog may contain affiliate links. I am disclosing this in accordance with the Federal Trade Commission's 16 CFR, Part 255: "Guides Concerning the Use of Endorsements and Testimonials in Advertising. This article is for informational purposes only. It is not intended to treat, diagnose, cure, or prevent disease. This article has not been reviewed by the FDA. Always consult with your primary care physician or naturopathic doctor before making any significant changes to your health and wellness routine. Editor's Note: This blog post was originally published in April 2013 and has been updated for accuracy. (March 2018) Bacteria that give a positive result in the Gram stain test Rod-shaped gram-positive Bacillus anthracis bacteria in a cerebrospinal fluid sample stand out from round white blood cells, which also accept the crystal violet stain. Violet-stained gram-positive cocci and pink-stained gram-negative bacilli In bacteriology, gram-positive bacteria are bacteria that give a positive result in the Gram stain test, which is traditionally used to quickly classify bacteria into two broad categories according to their type of cell wall. Gram-positive bacteria take up the crystal violet stain used in the test, and then appear to be purple-coloured when seen through an optical microscope. This is because the thick peptidoglycan layer in the bacterial cell wall retains the stain after it is washed away from the rest of the sample, in the decolorization stage of the test. Conversely, gram-negative bacteria cannot retain the violet stain after the decolorization step; alcohol used in this stage degrades the outer membrane of gram-negative cells, making the cell wall more porous and incapable of retaining the crystal violet stain. Their peptidoglycan layer is much thinner and sandwiched between an inner cell membrane and a bacterial outer membrane, causing them to take up the counterstain (safranin or fuchsine) and appear red or pink. Despite their thicker peptidoglycan layer, gram-positive bacteria are more receptive to certain cell wall targeting antibiotics than gram-negative bacteria, due to the absence of the outer membrane.[1] Characteristics Gram-positive and gram-negative cell wall structure Structure of gram-positive cell wall In general, the following characteristics are present in gram-positive bacteria:[2] Cytoplasmic lipid membrane Thick peptidoglycan layer Teichoic acids and lipoids are present, forming lipoteichoic acids, which serve as chelating agents, and also for certain types of adherence. Peptidoglycan chains are cross-linked to form rigid cell walls by a bacterial enzyme DD-transpeptidase. A much smaller volume of periplasm than that in gram-negative bacteria. Only some species have a capsule, usually consisting of polysaccharides. Also, only some species are flagellates, and when they do have flagella, have only two basal body rings to support them, whereas gram-negative have four. Both gram-positive and gram-negative bacteria commonly have a surface layer called an S-layer. In gram-positive bacteria, the S-layer is attached to the peptidoglycan layer. Gram-negative bacteria's S-layer is attached directly to the outer membrane. Specific to gram-positive bacteria is the presence of teichoic acids in the cell wall. Some of these are lipoteichoic acids, which have a lipid component in the cell membrane that can assist in anchoring the peptidoglycan. Classification Along with cell shape, Gram staining is a rapid method used to differentiate bacterial species. Such staining, together with growth requirement and antibiotic susceptibility testing, and other macroscopic and physiologic tests, forms the full basis for classification and subdivision of the bacteria (e.g., see figure and pre-1990 versions of Bergey's Manual). Species identification hierarchy in clinical settings Historically, the kingdom Monera was divided into four divisions based primarily on Gram staining: Firmicutes (positive in staining), Gracilicutes (negative in staining), Mollicutes (neutral in staining) and Mendocutes (variable in staining).[3] Based on 16S ribosomal RNA phylogenetic studies of the late microbiologist Carl Woese and collaborators and colleagues at the University of Illinois, the monophyly of the gram-positive bacteria was challenged,[4] with major implications for the therapeutic and general study of these organisms. Based on molecular studies of the 16S sequences, Woese recognised twelve bacterial phyla. Two of these were gram-positive and were divided on the proportion of the guanine and cytosine content in their DNA. The high G + C phylum was made up of the Actinobacteria and the low G + C phylum contained the Firmicutes.[4] The Actinobacteria include the Corynebacterium, Mycobacterium, Nocardia and Streptomyces genera. The (low G + C) Firmicutes, have a 45–60% GC content, but this is lower than that of the Actinobacteria.[2] Importance of the outer cell membrane in bacterial classification The structure of peptidoglycan, composed of N-acetylglucosamine and N-acetylmuramic acid Although bacteria are traditionally divided into two main groups, gram-positive and gram-negative, based on their Gram stain retention property, this classification system is ambiguous as it refers to three distinct aspects (staining result, envelope organization, taxonomic group), which do not necessarily coalesce for some bacterial species.[5][6][7][8] The gram-positive and gram-negative staining response is also not a reliable characteristic as these two kinds of bacteria do not form phylogenetic coherent groups.[5] However, although Gram staining response is an empirical criterion, its basis lies in the marked differences in the ultrastructure and chemical composition of the bacterial cell wall, marked by the absence or presence of an outer lipid membrane.[5][9] All gram-positive bacteria are bounded by a single-unit lipid membrane, and, in general, they contain a thick layer (20–80 nm) of peptidoglycan responsible for retaining the Gram stain. A number of other bacteria—that are bounded by a single membrane, but stain gram-negative due to either lack of the peptidoglycan layer, as in the Mycoplasmas, or their inability to retain the Gram stain because of their cell wall composition—also show close relationship to the Gram-positive bacteria. For the bacterial cells bounded by a single cell membrane, the term monoderm bacteria has been proposed.[5][9] In contrast to gram-positive bacteria, all typical gram-negative bacteria are bounded by a cytoplasmic membrane and an outer cell membrane; they contain only a thin layer of peptidoglycan (2–3 nm) between these membranes. The presence of inner and outer cell membranes defines a new compartment in these cells: the periplasmic space or the periplasmic compartment. These bacteria have been designated as diderm bacteria.[5][9] The distinction between the monoderm and diderm bacteria is supported by conserved signature indels in a number of important proteins (viz. DnaK, GroEL).[5][6][9][10] Of these two structurally distinct groups of bacteria, monoderms are indicated to be ancestral. Based upon a number of observations including that the gram-positive bacteria are the major producers of antibiotics and that, in general, gram-negative bacteria are resistant to them, it has been proposed that the outer cell membrane in gram-negative bacteria (diderms) has evolved as a protective mechanism against antibiotic selection pressure.[5][6][9][10] Some bacteria, such as Deinococcus, which stain gram-positive due to the presence of a thick peptidoglycan layer and also possess an outer cell membrane are suggested as intermediates in the transition between monoderm (gram-positive) and diderm (gram-negative) bacteria.[5][10] The diderm bacteria can also be further differentiated between simple diderms lacking lipopolysaccharide, the archetypical diderm bacteria where the outer cell membrane contains lipopolysaccharide, and the diderm bacteria where outer cell membrane is made up of mycolic acid.[7][10][11] Exceptions In general, gram-positive bacteria are monoderms and have a single lipid bilayer whereas gram-negative bacteria are diderms and have two bilayers. Some taxa lack peptidoglycan (such as the class Mollicutes, some members of the Rickettsiales, and the insect-endosymbionts of the Enterobacteriales) and are gram-variable. This, however, does not always hold true. The Deinococcus-Thermus bacteria have gram-positive stains, although they are structurally similar to gram-negative bacteria with two layers. The Chloroflexi have a single layer, yet (with some exceptions[12]) stain negative.[13] Two related phyla to the Chloroflexi, the TM7 clade and the Ktedonobacteria, are also monoderms.[14][15] Some Firmicute species are not gram-positive. These belong to the class Mollicutes (alternatively considered a class of the phylum Tenericutes), which lack peptidoglycan (gram-indeterminate), and the class Negativicutes, which includes Selenomonas and stain gram-negative.[11] Additionally, a number of bacterial taxa (viz. Negativicutes, Fusobacteria, Synergistetes, and Elusimicrobia) that are either part of the phylum Firmicutes or branch in its proximity are found to possess a diderm cell structure.[8][10][11] However, a conserved signature indel (CSI) in the HSP60 (GroEL) protein distinguishes all traditional phyla of gram-negative bacteria (e.g., Proteobacteria, Aquificae, Chlamydiae, Bacteroidetes, Chlorobi, Cyanobacteria, Fibrobacteres, Verrucomicrobia, Planctomycetes, Spirochetes, Acidobacteria, etc.) from these other atypical diderm bacteria, as well as other phyla of monoderm bacteria (e.g., Actinobacteria, Firmicutes, Thermotogae, Chloroflexi, etc.).[10] The presence of this CSI in all sequenced species of conventional LPS (lipopolysaccharide)-containing gram-negative bacterial phyla provides evidence that these phyla of bacteria form a monophyletic clade and that no loss of the outer membrane from any species from this group has occurred.[10] Pathogenesis Colonies of a gram-positive pathogen of the oral cavity, Actinomyces sp. In the classical sense, six gram-positive genera are typically pathogenic in humans. Two of these, Streptococcus and Staphylococcus, are cocci (sphere-shaped). The remaining organisms are bacilli (rod-shaped) and can be subdivided based on their ability to form spores. The non-spore formers are Corynebacterium and Listeria (a coccobacillus), whereas Bacillus and Clostridium produce spores.[16] The spore-forming bacteria can again be divided based on their respiration: Bacillus is a facultative anaerobe, while Clostridium is an obligate anaerobe.[17] Also, Rathybacter, Leifsonia, and Clavibacter are three gram-positive genera that cause plant disease. Gram-positive bacteria are capable of causing serious and sometimes fatal infections in newborn infants.[18] Novel species of clinically relevant gram-positive bacteria also include Catabacter hongkongensis, which is an emerging pathogen belonging to Firmicutes. [19] Bacterial transformation Transformation is one of three processes for horizontal gene transfer, in which exogenous genetic material passes from a donor bacterium to a recipient bacterium, the other two processes being conjugation (transfer of genetic material between two bacterial cells in direct contact) and transduction (injection of donor bacterial DNA by a bacteriophage virus into a recipient host bacterium).[20] In transformation, the genetic material passes through the intervening medium, and uptake is completely dependent on the recipient bacterium.[20] As of 2014 about 80 species of bacteria were known to be capable of transformation, about evenly divided between gram-positive and gram-negative bacteria; the number might be an overestimate since several of the reports are supported by single papers.[20] Transformation among gram-positive bacteria has been studied in medically important species such as Streptococcus pneumoniae, Streptococcus mutans, Staphylococcus aureus and Streptococcus sanguinis and in gram-positive soil bacterium Bacillus subtilis, Bacillus cereus.[21] Orthographic note The adjectives Gram-positive and Gram-negative derive from the surname of Hans Christian Gram; as eponymous adjectives, their initial letter can be either capital G or lower-case g, depending on which style guide (e.g., that of the CDC), if any, governs the document being written.[22] This is further explained at Gram staining § Orthographic note. 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