

IMMUNOLOGY AND MEDICAL MICROBIOLOGY

Normal microbial flora of human body and host parasite relationship

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Normal microbial flora of human body

Microbial investigations on foetus have revealed that not a single microbe inhabits its skin, hair, teeth, gastrointestinal tract, ear, respiratory tract when it is in the womb. However, as the infant passes through the mother's birth canal on its way into the outside world, the microbes start colonizing the infant body. It has been found that a drop of healthy woman's normal vaginal secretion contains millions of microbes. Therefore, at the time of birth, infant acquires microbes from mother and the external environment. Every kiss, cuddle and suckle transmits bacteria. Within 24 hours of birth, the infant body is colonized by several different species of microbes. However, some times our normal microflora causes mischief resulting into body odor, peptic ulcers, periodontitis, urinary tract infection, etc. Trouble often begins when our internal or external ecosystem is disrupted and microbes find themselves in habitats to which they are not adapted.

The human body contains a large variety of microbes, most of them performing tasks that are useful or even essential to human survival. Those that are expected to be present, and under normal circumstances do not cause disease, are termed 'normal flora'. It is estimated that 5,000 to 10,000 different species of microbes live in the human body. Microbial cells are much smaller than human cells, and there are about 1000 trillion (10^{15}) microbes, ten times as many as human cells in the body (10^{14}). Though normal flora are found on all surfaces exposed to the environment (on the skin and eyes, in the mouth, nose, small intestine, and colon), the vast majority of bacteria live in the large intestine.

A wide variety of microbes have been found associated with other living forms in different ways. The organisms located on the surface of other organisms are called 'ectosymbiont'. Similarly the organisms located inside other organisms are called 'endosymbiont'. There are also some organisms which can be found in surface as well as inside the body. Such organisms are called 'ecto/endosymbiont'. Like other animals, human body also supports growth of a variety of microorganisms based on symbiosis. The organisms including bacteria, fungi and protozoa are normally present in some anatomical locations of the body and do not cause any disease in normal situations, hence collectively called 'normal microbiota'.

Normal microorganisms easily colonise at different anatomical locations of the body and thrive in these sites without causing any apparent harm to the host. The study of normal microflora in human body helps in understanding the mechanisms of colonization, commensalism, beneficial effects and causation of disease in certain conditions. The normal microorganisms found to be associated with different parts of human body are described here.

A. Eyes

Eyes are exposed to external environment, hence they come in contact with several microbes. The conjunctival flora is normally sparse probably because of lysozyme, secreted in tears. Lysozyme is known to inhibit growth of bacteria. It has been observed that certain bacteria such as *Staphylococcus epidermidis*, *S. aureus*, *Haemophilus* spp, *Streptococcus pneumoniae*, *Corynebacteria*, *Neisseriae* and *Moraxellae* may be present on conjunctiva (Table 1). In normal situations, these organisms do not cause any harm to eyes. However, in certain circumstances such as injury to the eyes, these organisms may cause opportunistic infections.

Table 1: Normal microflora of eyes

1. Coagulase negative Staphylococci	2. <i>Haemophilus</i> spp.
3. <i>Staphylococcus aureus</i>	4. <i>Streptococci</i> (different species)
5. <i>Corynebacterium</i> spp.	6. <i>Neisseria</i> spp.
7. <i>Moraxella</i> spp.	

B. Ear

Ear is also exposed to the external environment. Hence, there is normal microflora present in the ear too (Table 2). In addition, normal microflora present on the skin has been found in ear also. Microorganisms such as *Pseudomonas* may result into opportunistic infections in the ear (Fig. 1A).

Table 2: Normal microflora of ear

1. Coagulase negative Staphylococci	2. Diphtheroids
3. <i>Pseudomonas</i> spp.	4. Occasionally enterobacteria

C. Nasopharynx

The nasopharynx and trachea contain primarily those bacterial genera found in the normal oral cavity (for example, alpha- and β -hemolytic streptococci (Fig. 1B)), however, staphylococci, neisseriae, diphtheroids, and others are also present (Table 3). Potentially pathogenic organisms such as *Haemophilus*, mycoplasmas, and pneumococci may also be found in the pharynx. The upper respiratory tract is so often the site of initial colonization by pathogens such as *Neisseria meningitidis*, *C. diphtheriae*, *Bordetella pertussis* and could be considered the first region of attack for such organisms. In contrast, the lower respiratory tract (small bronchi and alveoli) is usually sterile, because particles of size of bacteria do not readily reach there. If bacteria do reach these regions, they encounter host defense mechanisms, such as alveolar macrophages, that are not present in the pharynx.

Table 3: Normal microflora of nose and Nasopharynx

1. Coagulase negative Staphylococci	2. Viridans Streptococci
3. <i>Staphylococcus aureus</i>	4. <i>Haemophilus</i> spp.
5. <i>Streptococcus pneumoniae</i>	6. <i>Neisseria</i> spp.

D. Skin

The sweaty and sebaceous secretions of adolescence make the skin highly susceptible to colonization by microbes. According to an estimate, entire skin (approximately 2 square meters)

of an adult human body can support approximately 10^{10} bacteria commensally. The organisms normally found are listed in Table 4. The skin is a very strong mechanical barrier to microbial invasion and only a few microorganism can penetrate the skin because the outer layer is constituted by thick closely packed cells known as keratinocytes. The cells produce keratin which is generally resistant to enzymatic degradation. The shedding of the outer epithelial cells of the skin also removes many microflora that attach to the outer skin surface. The physiology as well as internal structure of the skin varies from one part of the body to another. Based on the type of the skin, the type of skin micro-flora also varies. The outer skin surface (epidermis) is not suitable for colonization of bacteria because of many factors. The dryness of the skin due to changes in environment is responsible for keeping the skin flora in dormant state. The slight acidic pH of the skin due to secretions and sweat gland prevents colonization of microorganisms. The high concentration of salt in sweat makes the skin surface hyper-osmotic which can be lethal to a variety of microbial cells. The inhibitory substances on the skin also prevent colonization of pathogenic microorganism. The lysozyme released by sweat glands kills *Staphylococcus epidermidis* and other Gram positive bacteria. Sweat also produces antimicrobial peptides called cathelicidins e.g. germicidal which protects skin from pathogenic organisms. The oil glands secrete lipids which may be broken down by Gram positive bacteria. The lipids are broken down into unsaturated fatty acids which have strong antibacterial action against Gram negative bacteria and some fungi.

Most of the skin bacteria are found on the superficial skin cells, colonising dead cells (Fig. 1C). The secretions of closely associated skin glands provide nutrients to these bacteria such as *Staphylococcus epidermidis*, *Staph. Aureus* (Fig. 1D), *Corynebacteria* and yeasts such as *Putyrosporum ovale* and *P. orbiculare* fixed on the scalp. The ‘ringworm’ infections are caused by dermatophytic fungi that colonise the skin. The lipophilic Gram positive rods such as *Propionibacterium acenes* are present in oil glands. Though these bacteria are generally harmless but sometimes they may be associated with skin disease acne volgares. Blockheads or pimples can result from the colonization of *P. acenes*. Various species of streptococci are also found on the skin. *Mycobacteria* spp. are occasionally present on the skin.

E. Nails

The microflora of the normal nails is generally similar to that of the skin. Dust particles and other extraneous materials may get trapped under the nail, depending on what the nail contacts. In addition to resident skin flora, these dust particles may carry fungi and bacilli. *Aspergillus*, *Penicillium*, *Cladosporium*, and *Mucor* are the major types of fungi found under the nails.

Table 4: List of commonly found normal microorganisms on human skin

- | | |
|---|-------------------------------------|
| 1. <i>Streptococcus</i> (various species) | 2. <i>Candida</i> spp. |
| 3. <i>Staphylococcus aureus</i> | 4. Coagulase negative Staphylococci |
| 5. <i>Bacillus</i> spp | 6. <i>Mycobacterium</i> spp. |
| 7. <i>Malassezia furfur</i> | 8. Diphtheroids |
| 9. <i>Propionibacterium acenes</i> | |

F. Gastrointestinal tract

Many of the bacteria in the digestive tract, collectively referred to as 'gut flora', are able to break down certain nutrients such as complex carbohydrates that humans otherwise can not digest. The majority of these commensal bacteria are anaerobes, meaning they survive in an environment with no oxygen. Many of the bacteria of the normal flora can act as opportunistic pathogens at times of lowered immunity.

More than 500 bacterial species that are present in the normal human gut are generally beneficial. They synthesize vitamins such as folic acid, vitamin K and biotin, and they ferment complex indigestible carbohydrates. Common beneficial bacteria in the normal flora of the gut include *Lactobacillus* species, which produce lactic acid in the gut. The presence of these bacteria inhibit the growth of potentially pathogenic bacteria (usually through competitive exclusion) and some beneficial bacteria are consequently sold as probiotic dietary supplements.

Probiotic, literally means 'for' or 'pro' life, has now been defined as live preparations of individual or consortium of microorganisms, when ingested has beneficial effect on the consumer. These are very helpful in patients suffering from diarrhea and also to those who have been given antibiotics to treat gastrointestinal infections. Probiotics have been used as growth promoters, immunopotentiators, anti-tumour, anti-cholesterol and for lactose intolerance. A good probiotic agent should have following features: a. non-pathogenic, b. nontoxic, c. resistant to gastric acid, d. adhere to gut epithelial tissue, e. produce antibacterial substances. It should persist, albeit for short periods in the gastro-intestinal tract influencing metabolic activities like cholesterol assimilation, lactose activity and vitamin production.

A variety of microorganisms including bacteria, moulds and yeast have been used as probiotics. However majority of the commercially available probiotics are composed of bacteria. Among bacteria, lactic acid bacteria (LAB) are more popular. *Lactobacillus acidophilus*, *L. casei*, *L. lactis*, *L. helveticus*, *L. salivarius*, *L. plantum*, *L. bulgaricus*, *L. rhamnosus*, *L. johnsonii*, *L. reuteri*, *L. fermentum*, *L. del brueckii*, *Streptococcus thermophilus*, *Enterococcus faecium*, *E. faecalis*, *Bifidobacterium bifidum*, *B. breve*, and *B. longum* are commonly used bacterial probiotics. Probiotics can be in powder form, liquid form, gel, paste, granules or available in the form of capsules, sachets, etc.

In India, use of probiotics in livestock and poultry husbandry is quite common. Some probiotics preparations including Sporolac and yogurt (*L. bulgaricus* + *L. thermophilus*) are commercially available in India for human use. Sporolac is manufactured using Sporolactobacilli. Lactobacilli solution is an example of a probiotic, usually given to paediatric patients in India. Recently ViBact (a new probiotics made up of genetically modified *Bacillus mesentericus*) has been introduced in India as an alternate to B-complex capsules.

Normal microbial flora of different organs of gastrointestinal tract is described here.

i. Oral cavity

The normal microflora that are not easily removed by mechanical clearance adhere to teeth and gums in the oral cavity. With the appearance of a baby's first teeth come new opportunities for microbial colonization. The bacteria which are removed by flushing the oral cavity reach to

stomach and are destroyed by hydrochloric acid. The continuous shedding of the epidermal cells of the oral cavity also shed the microorganisms present in the oral cavity. The microorganisms colonize oral cavity within few hours of the birth of the baby. In the beginning, the microbes belonging to various genera such as *Streptococcus*, *Lactobacillus*, *Neisseria*, *Actinomyces*, *Salmonella* and some yeast are present. These microbes colonising in oral cavity in early years of life are normally aerobes and obligatory aerobes. Later on when first teething erupts, the aerobes such as *Porphyromonas* spp, *Prevotella* spp and a few other bacterial species also colonise the oral cavity due to anaerobic environment present between the spaces of teeth guard gums. When teeth start growing the space is filled up and other bacteria namely *Streptococcus parasanguis* and *S. mutans* attach to the enamel of teeth. The bacteria present in saliva are *S. salivarius*. The bacterial population normally present in oral cavity leads to formation of dental plaque, cavities, infection of gums etc. Other microbes found in oral cavity are diphtheroids, *Eikenella corrodense*, *S. aureus*, beta-haemolytic streptococci, *Haemophilus* spp, *Candida* spp. and Viridans Streptococci (Table 5).

Table 5: Normal microflora of oral cavity	
Coagulase negative Staphylococci	<i>Branhamella catarrhalis</i>
Viridans Streptococci	<i>Staphylococcus aureus</i>
<i>Haemophilus</i> spp.	<i>Streptococcus pneumoniae</i>
<i>Neisseria</i> spp.	<i>Candida</i> spp.
<i>Porphyromonas</i> spp.	<i>Prevotella</i> spp.
<i>Treponema</i> spp.	<i>Fusobacterium</i> spp.
<i>Veillonella</i> spp.	Diphtheroids
<i>Actinomyces</i> spp.	<i>Eikenella corrodense</i>
Beta haemolytic streptococci (not group A)	

Large populations of these organisms on humans are the cause of body odor and thought to play a part in the formation of acne.

Dental caries

Tooth decay (dental caries) is the commonest disease of human beings. It is caused by bacteria. Colonization of pellicle (organic covering of hard enamel formed by absorption of acidic glycoproteins from saliva) by *Streptococcus oralis*, *S. mitis* and *S. gordonii* results into formation of dental plaque. It has been found out that these bacteria adhere to the pellicle by hydrophobic, ionic and lectin-like interactions. The formation of dental plaque catalyses attachment of other bacteria by the process of coaggregation (the result of cell-to-cell recognition between genetically distinct bacteria). The most important bacterial species which play an important role in coaggregation are *Acetivomyces viscosus*, *A. naeslundii* and *S. gordonii*. After colonization of pellicle by these bacteria, a microenvironment is created that allows *S. mutans* and *S. sobrinus* to attach to the tooth surface. Glycosyl transferase (an enzyme produced by streptococci)

catalyzes formation of extracellular water soluble and water insoluble ‘glucan’ polymers and other carbohydrates from glucose moiety of sucrose. Glucans are composed of glucose units. Glucans act as cementing materials between bacterial cells resulting into formation of dental plaque ecosystem. Studies have indicated that dental plaque is one of the most dense aggregation of different bacteria in the body. The formation of dental plaque results in to creation of low oxidation reduction potential on the surface of tooth. This allows growth of anaerobic bacteria such as *Bacteriodes melaninogenicus*, *B. oralis* and *Veillonella alcalescens*. The resident bacteria start producing, lactic acid, acetic acid and formic acids from sucrose and other carbohydrates. Since the plaques are not permeable, the produced acids are not diluted or neutralized. The accumulation of acids results into demineralization of enamel to produce lesions on the tooth. These lesions lead to dental caries. Dental caries is characterized by a spot on a tooth where minerals have melted away and a hole has formed due to bacterial infection. This process is called demineralization. Areas of demineralization, bleeding gums or visible plaque on teeth means that bacteria that can cause formation of cavities or infection of the gums are not being removed regularly. Feeding bottles containing something other than milk or water (e.g., soda, juices) increase child’s risk for tooth decay. High frequency of sugar containing foods (candy, sugary foods, beverages with sugar), can increase acid production and contribute to mineral loss and tooth decay. Strict oral hygiene and regular brushing of teeth minimizes chances of dental caries.

ii. Stomach

The stomach is a relatively hostile environment for bacteria because of its acidity. Stomach however contains bacteria swallowed with the food and those dislodged from the mouth. Stomach has very high acidic pH (between 2-3). Acidity lowers the bacterial count, which is highest (approximately 10^3 to 10^6 organisms/g of contents) after meals and lowest (frequently undetectable) after digestion. The normal bacteria in stomach are of *Streptococcus* spp, *Staphylococcus* spp and *Lactobacillus* (Table 6). Some *Helicobacter* species can colonize the stomach and are associated with gastritis and peptic ulcers. Almost 50% of the human beings all over the globe have been found to be colonized by *H. pylori* in their stomach. The yeast belonging to *Candida* spp. may also be present. Only those bacteria which are resistant to acidic pH can pass from stomach to intestine.

Table 6: Normal microflora of stomach

- | | |
|-------------------------------|-----------------------------------|
| 1. <i>Streptococci</i> spp. | 2. <i>Staphylococcus</i> spp. |
| 3. <i>Lactobacillus</i> spp. | 4. <i>Peptostreptococcus</i> spp. |
| 5. <i>Helicobacter pylori</i> | |

iii. Small intestine

It can be divided into three parts 1. duodenum, 2. jejunum and 3. ileum. The first 25 cm area of small intestine is duodenum. Very few bacteria are present in this region because of the reason that it has effect of the acidic juices of stomach and inhibitory effect of bile and pancreatic secretions. Most common bacteria are Gram positive cocci and rods such as *Enterobacter faecalis*, diphtheroids, Lactobacilli that are present in the jejunum (middle part of the small intestine). Among yeast, *Candida albicans* is occasionally found in this part of intestine. The

distal part of intestine is ileum in which pH starts rising and is more towards alkaline. Due to rise in pH, anaerobic Gram negative bacteria and many members of the family *Enterobacteriaceae* start colonising this area of intestine. Thus the common bacteria residing in small intestine belong to Enterococci, Enterobacteria, *Mycobacterium* spp, *Clostridium* spp., Bacteriodes and *Lactobacillus* spp. (Table 7).

Table 7: Normal microflora of small intestine

1. Members of <i>Enterobacteriaceae</i>	2. <i>Lactobacillus</i> spp.
3. <i>Enterococci</i>	4. <i>Bacteroides</i> spp.
5. <i>Mycobacterium</i> spp.	6. <i>Clostridium</i> spp.

Although the normal flora of the gut can inhibit pathogens, many of its members can produce disease in humans. Anaerobes in the intestinal tract are the primary agents of intra-abdominal abscesses and peritonitis. Bowel perforations produced by appendicitis, cancer, infarction, surgery, or gunshot wounds almost always seed the peritoneal cavity and adjacent organs with the normal flora. Anaerobes can also cause problems within the gastrointestinal lumen. Treatment with antibiotics may allow certain anaerobic species to become predominant and cause disease. For example, *Clostridium difficile*, which can remain viable in a patient undergoing antimicrobial therapy, may produce ‘pseudomembranous colitis’. Other intestinal pathologic conditions or surgery can cause bacterial overgrowth in the upper small intestine. Anaerobic bacteria can then deconjugate bile acids in this region and bind available vitamin B12 so that the vitamins and fats are mal-absorbed. In these situations, the patient has usually been compromised in some way; therefore, the infection caused by the normal intestinal flora is secondary to another already existing problem.

iv. Large intestine

It is also known as colon. It supports a diversity of microorganisms. Hence large intestine has very high counts of organisms (10^{12} organisms/gm wet weight of stool). The large intestine acts as a large fermentor of microbes consisting of Gram negative bacteria and anaerobes. In addition, Gram positive spore forming and non spore forming rods are also present in the colon (Table 8). Among the members of the family *Enterobacteriaceae*, *E. coli* (Fig. 1E) is more abundant than other species. In colon, yeasts such as *Candida albicans* are also present along with some protozoa without apparently doing any harm to the body. *Trichomonas hominis*, *Entamoeba hartmani*, *Endolimax nana* and *Entamoeba butschlii*. A large number of microbes are excreted in the faeces (3×10^{13} microbes) daily out of the human body. This number is due to the peristaltic movement, shedding of surface epithelium cells to which organisms are attached, and the flow of mucous flushing bacteria out from the intestine. Despite huge loss of bacteria from large intestine, the number of bacteria is maintained in the colon due to rapid multiplication of microorganisms in this region of the gut. The number becomes double once or twice a day.

In the early life of an infant, members of the Gram positive genus *Bifidobacterium* are acquired during breast feeding due to the presence of special disaccharide aminosugar which is a growth factor for Bifidobacters. However, babies fed on commercial formula preparations *Lactobacillus*

spp. predominates because it lacks the growth factor required for Bifidobacters. As the babies are subjected to solid diet, the colon is colonised by gram negative bacteria, and later in the adults diverse form of microbes are established.

Table 8: Normal microflora of large intestine

1. <i>Lactobacillus</i> spp.	2. Enterococci
3. <i>Bacteroides</i> spp.	4. <i>Mycobacterium</i> spp.
5. <i>Clostridium</i> spp.	6. <i>Streptococcus</i> (various species)
7. <i>Staphylococcus aureus</i>	8. Coagulase negative Staphylococci
9. <i>Klebsiella</i> spp.	10. <i>Fusobacterium</i> species
11. <i>Peptostreptococcus</i> spp.	12. <i>E. coli</i>
13. <i>Proteus</i> spp.	14. <i>Actinomyces</i> spp.
15. <i>Acinetobacter</i> spp.	16. <i>Pseudomonas</i> spp.

The large intestine is home, amazingly, for around 400 different species of microbes. Of these, about 95-99 % are anaerobes including *Bacteroides*, *Bifidobacterium*, *Eubacterium*, *Peptostreptococcus*, and *Clostridium*. In this region of gastrointestinal tract, these organisms produce metabolic waste products such as acetic, butyric, and lactic acids.

G. Urogenital microflora

A variety of microbes are normally present in urogenital system (Table 9). The anterior urethra of humans contains *S. epidermidis*, enterococci, and diphtheroids. *E coli*, *Proteus*, and *Neisseria* (nonpathogenic species) are reported occasionally. Because of the normal flora residing in the urethra, care must be taken in clinically interpreting urine cultures; urine samples may contain these organisms at a level of 10^4 /ml if a midstream (clean sample) urine sample is not obtained.

The type of bacterial flora found in the vagina depends on the age, pH, and hormonal levels of the host. *Lactobacillus* spp. (Fig. 1F) predominate in female infants (vaginal pH, approximately 5) during the first month of life. Glycogen secretion seems to cease from about one month of age to puberty. During this time, diphtheroids, *S. epidermidis*, streptococci, and *E coli* predominate at a higher pH (approximately pH 7). At puberty, glycogen secretion resumes, the pH drops, and women acquire an adult flora in which *L. acidophilus*, corynebacteria, peptostreptococci, staphylococci, streptococci, and *Bacteroides* predominate. After menopause, pH again rises, less glycogen is secreted, and the flora returns to that found in prepubescent females. Yeasts (*Torulopsis* and *Candida*) are occasionally found in the vagina (10 to 30 percent of women); these sometimes increase and cause vaginitis.

In women the change from the normal, non-clinical presence of the *Candida* in vagina to a pathological attack may be the result of various factors including stress, lack of sleep, sickness, poor diet, extreme intake of sugary foods, pregnancy, periods, intake of birth control pills,

antibiotics treatment, steroid medicines, diseases such as poorly-controlled diabetes and immunodeficiency infections including HIV. The over growth of *Candida* in vagina may lead to a condition called ‘vaginal thrush’. *Candida* is a yeast-like fungus which exists as part of the normal flora of vagina. It usually doesn't cause problems because normal bacteria (flora) in the body keep its growth in check. Mainly three species of *Candida* viz., *C. albicans*, *C. tropicalis*, *C. glabrata* have been found associated with vaginal thrush. The two prime symptoms of vaginal thrush are the vaginal discharge and the itch. Some soreness and swollen labia and a burning sensation independent of urination may be experienced. Vaginal thrush is very common. About 75 percent of women have a yeast infection during their lives.

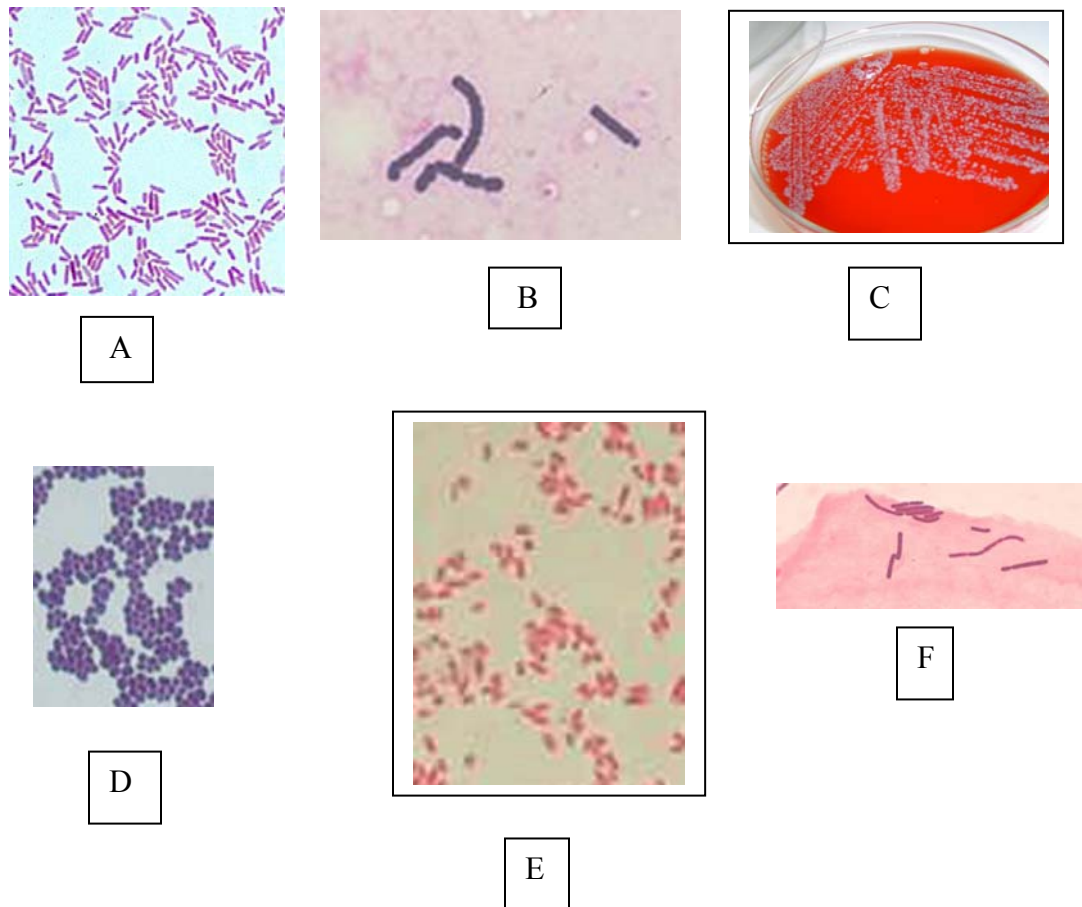


Fig. 1: Important Microbial Flora of Human Body

- A. *Pseudomonas aeruginosa* frequently isolated from ear.
- B. *Streptococcus* spp. A predominant normal bacterial species of nasopharynx
- C. Numerous bacterial colonies on blood agar plate after swabbing from normal human skin.
- D. *Staphylococcus aureus*, a predominant normal microflora of skin.
- E. *E. coli*, a predominant normal bacterial species found in large intestine
- F. *Lactobacillus* spp. found in urogenital system

Thrush can be effectively treated using antifungal medicines including butoconazole, clotrimazole, miconazole, nystatin, tioconazole and terconazole in the form of creams, tablets, ointments or suppositories that are inserted into the vagina. Appropriate hormonal treatment and hygiene are also useful in controlling Candida infection.

Table 9: Urogenital microflora

1. Coagulase negative Staphylococci	2. <i>Mycobacterium</i> spp.
3. <i>Bacteroides</i> spp.	4. <i>Fusobacterium</i> species
5. <i>Peptostreptococcus</i> spp.	6. Diphtheroids
7. <i>Streptococcus</i> (various species)	8. <i>Lactobacillus</i> spp.
9. <i>Peptostreptococcus</i> spp.	10. <i>Candida</i> spp.
11. <i>Clostridium</i> spp.	12. <i>Gardenerella vaginalis</i>

Nosocomial infections

The word ‘nosocomial’ is derived from Greek word for ‘hospital’. Nosocomial infection refers to the infections acquired by the persons in the hospital when they are admitted there for treatment. According to an estimate 5-15 % of all hospital patients acquire some type of nosocomial infection and about 20, 000 people die of nosocomial infections annually. Nosocomial infections may also be acquired by doctors, nurses or visitors.

Since hospitals receive patients suffering from different diseases caused by microbial pathogenic agents, the hospital environment is contaminated with a variety of pathogenic organisms. Hence, there are chances that hospital staff and patients may get infected with organisms. The nosocomial infections are governed by a number of factors including microorganisms in the hospital environment, immuno-compromised status of the host and the chain of transmission in the hospital.

Though efforts are made to check microbes, the hospital environment is major reservoir of pathogenic organisms. Mainly gram positive bacteria *Staphylococcus aureus* and gram negative bacteria such as *E. coli* and *Pseudomonas aeruginosa* have been found to be nosocomial infections. Drug resistant *Pseudomonas aeruginosa* strains are known to cause opportunistic skin infection particularly in burn and surgical cases. The most common nosocomial infections have been summarised in Table 10.

Though most hospitals have their own system (hospital infection control programmes) to prevent and control nosocomial infections, some basic procedures can be of great help in limiting the load of pathogenic organisms in the hospital environment. Hospital floors, bath rooms, toilets and latrines, surgical rooms, hospital beds must be hygienically managed using appropriate methods of disinfection. There should be periodic microbiological examination of hospital instruments such as respirator, tracheal tubes, catheters and other equipment. Appropriate fumigation of various rooms, wards and operation theaters should be undertaken regularly. The

contaminated materials such as used bandages, wound dressing material, surgical and other treatment waste including syringes etc must be hygienically (preferably by incineration) disposed of. Hospital paramedical staff should be educated about the use of hygienic principle.

Table 10: Commonly occurring nosocomial infections

Microorganism	Infections caused
<i>E. coli</i> , <i>Klebsiella</i> spp., <i>Proteus</i> spp. <i>Enterobacter</i> spp. and <i>Serratia marcescens</i>	Urinary tract infections, peritonitis, bacteremia, pneumonia, septicemia, gastrointestinal inflammation and neonatal meningitis
<i>Staphylococcus aureus</i>	Urinary and respiratory tract infections and endocarditis
Fungi (mostly <i>Candida albicans</i>)	Surgical site infections and pneumonia
<i>Enterococcus</i>	Urinary tract surgical site infections and endocarditis
<i>Pseudomonas aeruginosa</i>	Burns and surgical site infections, septicemia and pneumonia

Opportunistic infections

The microbial flora normal present in different anatomical locations of the body is normally harmless and many times protects body from invading pathogens. However under certain circumstances these resident microbial agents may produce diseases in the host. Such agents are known as opportunistic pathogens and infections caused by these microorganisms are called ‘opportunistic infections’. The opportunistic pathogens normally cause disease in weak and immuno-compromised hosts which have lowered resistant to infection. A number of microbial and non-microbial causes have been identified that may lead to lowered resistance to infection. These include infection with viral agents such as human immunodeficiency virus (HIV), malnutrition of host, alcoholism, cancer, diabetes, leukemia, surgical injuries and immuno-suppression induced by drug treatment, genetic diseases etc. The best example is that of *Bacteriodes* spp. which are normally present in the colon. In case of injuries to the intestine, if this organism gets entry into peritoneal cavity or pelvic tissue, it may cause formation of pus, and may travel through blood to many other tissues of the body.

E. coli is a predominant bacterial species in large intestinal. It does not cause any harm to host as long as it is present in large intestinal. However, if it gains access to other body parts such as urinary bladder, spinal chord, lungs, peritoneal cavity or wounds, it may cause disease in respective locations. Tooth decay and gum diseases are caused by the organisms which are considered as normal microflora of the oral cavity.

AIDS patients have often been found associated with opportunistic infection such as *Pneumocystis carinii*. Similarly other viral disease may be followed by infection with opportunistic organisms. Some viruses such as echoviruses and adenovirus are normally present in human beings. However, in compromised host, these viruses may cause opportunistic infections. Similarly, *Neisseria meningitidis* (normal resident of respiratory tract) and

Streptococcus pneumoniae (normal resident of nose and throat) may also cause opportunistic infections leading to serious diseases in certain circumstances.

Candida albicans is present as normal microflora of oral cavity, skin and vagina in the health individuals. But when the host is immuno-compromised due to a variety of reasons, the same *Candida* can cause 'oral thrush', infection of nails and 'vaginal thrush' which are opportunistic infections.

Oral thrush is also known as pseudomembranous candidiasis. The signs of oral thrush include the presence of plaques (white raised areas) loosely attached to the mucous membranes of the oral cavity. The plaques can be easily scraped, however this leaves the areas sore and often bleeding. The persons with dentures may suffer from chronic atrophic candidiasis which is characterized by generalized inflammation of the denture area. *Candida* species adhere to the denture surface and infect the area. Acute atrophic candidiasis affects mainly the tongue which becomes red, painful and sometimes bleeds. While the plaques may be visible, often this condition is characterized by general inflammation (erythema) of the denture area and a granular surface appearance. Oral thrush causes creamy white lesions, usually on tongue or inner cheeks. The lesions can be painful and may bleed slightly when scraped. In certain circumstances oral thrush may spread to gums, back throat, the roof of mouth and tonsils. Toddlers with mild oral thrush who are otherwise healthy need not to be treated because they recover from the infection without treatment. If the yeast infection develops after antibiotic treatment, adding of unsweetened yogurt to child's diet helps in restoring the natural balance of bacteria. Infants or older children with persistent thrush may need an antifungal treatment. If baby uses a pacifier or feeds from a bottle, wash and rinse nipples and pacifiers every day until the thrush clears up. If you're a healthy adult with oral thrush, you may be able to control the infection by eating unsweetened yogurt or taking acidophilus capsules or liquid. Yogurt and acidophilus don't destroy the fungus, but they can help restore the normal bacterial flora. Since garlic has antifungal and antibacterial properties, taking garlic capsules helps in controlling the oral thrush. Practice of good oral hygiene, use of yogurt or acidophilus capsules with antibiotics treatment, limiting the amount of sugar and yeast-containing foods including bread, beer and wine may reduce the risk of oral thrush.

Mode of transmission of infections

The infection or infectious disease may be transmitted from one person to another by direct contact or the disease causing agent may spread from one place to another by a variety of ways. The pathogen may be transmitted by person to person contact, water, food, air, insect vector, blood and blood products transfusion, from mother to foetus, etc. Different modes of transmission of diseases are briefly described with suitable examples.

A. Person to person contact

A number of bacterial, viral and fungal diseases have been identified that are easily transmitted from person to person by contact. Small pox (caused by human pox virus) and tuberculosis (caused by *Mycobacterium tuberculosis*) are two good examples of transmission of diseases by direct contact with the infected personal (Table 11). When the host and source or reservoir of pathogens came in contact with each other the transfer of infection takes place in the susceptible

host. The contact may be direct such as when a host physically touches the source of pathogen or may be indirect when transmission of pathogens from infected host to non infected occurs through an inanimate object such as use of common towel, eating utensils, drinking glass, use of common bedding, etc. Such intimate objects which are responsible for the transmission of infectious agents to uninfected hosts are called 'fomites'. Chicken pox is another good example of contact transmission. The dry scabs of the pox lesions are full of virus, the clothes, beddings, utensil of patients also get contaminated and the healthy persons coming in contact with these may get infection. Direct person-to-person transmission also occurs by touching, kissing or sexual contact (in case of sexually transmitted diseases such as AIDS, genital herpes, syphilis, etc), contact with oral, nasal and other body secretions may also transmit the diseases. Through placenta infection may be transmitted to foetus as in case of AIDS, Rubella and syphilis. Direct contact with animals or animal products may cause infection such as *Salmonella* and *Compylobacter* from poultry and poultry products. Rabies is transmitted by the bite of infected canine animals.

Table 11: Important diseases transmitted through contact

Name of etiologic agent	Type of pathogen	Disease
Human immunodeficiency virus (HIV)	Virus	AIDS
Varicella zoster virus (VZV)	Virus	Chicken pox
Influenza virus	Virus	Influenza
Small pox (Variola) virus	Virus	Small pox
<i>Bacillus anthracis</i>	Bacteria	Anthrax
<i>Brucella abortus</i> and <i>B. melitensis</i>	Bacteria	Brucellosis (Undulant fever)
<i>Mycobacterium tuberculosis</i> , <i>M. bovis</i>	Bacteria	Tuberculosis
<i>Trychophyton</i> spp., <i>Microsporum</i> spp., <i>Epidermophyton</i> spp.	Fungi	Ringworms

B. Air-borne transmission

A large number of viral and bacterial pathogens which cause respiratory diseases get-air borne during sneezing, coughing and talking. The pathogens are present in the air in the form of small 'aerosols' called 'droplet nuclei'. These aerosols can travel few meters to hundreds of kilometres through the air current and reach to susceptible host and cause infection/disease. These 'droplet nuclei' are major source of airborne infections in humans as well as animals. It has been observed that the pathogens remain viable and infective in air. Common cold is the best example of airborne infection caused during winter seasons (Table 12). Several other diseases such as pneumonia (bacterial or viral), influenza, tuberculosis, and whooping cough are transmitted by air.

Table 12: Important airborne diseases

Name of etiologic agent	Type of pathogen	Disease
Mumps virus	Virus	Mumps
Common cold viruses	Virus	Common cold
Rubella	Virus	German measles
Measles virus	Virus	Measles
<i>Bacillus anthracis</i>	Bacteria	Anthrax
<i>Bordetella pertussis</i>	Bacteria	Whooping cough
<i>Mycobacterium tuberculosis, M. bovis</i>	Bacteria	Tuberculosis
<i>Corynebacterium diphtheriae</i>	Bacteria	Diphtheria
<i>Mycoplasma pneumoniae</i>	Mycoplasma	Atypical pneumonia
<i>Chlamydia psittaci</i>	Chlamydia	Psittacosis
<i>Histoplasma capsulatum</i>	Fungus	Histoplasmosis

C. Water-borne transmission

A variety of human and animal infectious agents are transmitted through water particularly in developing countries where wide-spread chlorination facilities are not available (Table 13). The drinking water is often contaminated with faecal contents of animals, birds and some times humans. It is now well known that many pathogens are present in faeces of birds and animals which may contaminate the drinking water. When the people consume such contaminated water, they get infected. Giardiasis, amoebiasis, cholera, salmonellosis, hepatitis E and viral gastroenteritis are some of the common diseases transmitted through water. The causative agents of some of these water borne-borne diseases are summarised in Table 13. When contaminated water is used for washing vegetable and fruits that are consumed raw (without cooking) these could be important source of infection to humans. Similarly other food products such as milk or milk products if mixed with contaminated water and consumed without pasteurization or boiling may result into water-borne infections. The water borne mode of transmission is also called as 'faeco-oral' route of transmission of diseases.

The popularity of recreational activities which involve contact with water has grown world-wide. Recreational use of water such as swimming and water sports can transmit infections of eyes and ears etc. Several disease causing pathogens may be acquired while undertaking water-based recreation in marine, freshwater, hot tubs, spas and swimming pools. Following organisms may be transmitted by recreational use of water: *Aeromonas* spp., *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Shigella* spp., *E. coli* O157, *Salmonella* spp., *Campylobacter* spp., *Helicobacter pylori*, *Legionella* spp, *Giardia* spp., hepatitis A and Hepatitis E viruses, adenovirus and coxsackievirus

The use of water for air-conditioning leads to transmission of a bacterial pathogen called *Legionella pneumophila* which causes pneumonia in elderly and immunocompromized hosts. This is particularly so for air-conditioning in hospitals and old-age homes where vulnerable population of elderly people may be inadvertently exposed to such water-borne infections.

Table 13: Common water borne diseases

Name of etiologic agent	Type of pathogen	Disease
Enteroviruses	Virus	Gastroenteritis
Rotaviruses	Virus	Diarrhoea, gastroenteritis
Poliovirus	Virus	Polio
Hepatitis E virus	Virus	Hepatitis
<i>Vibrio cholerae</i>	Bacteria	Cholera
<i>Helicobacter pylori</i>	Bacteria	Peptic ulcers
<i>Salmonella enteritidis</i>	Bacteria	Diarrhoea
<i>Yersinia enterocolitica</i>	Bacteria	Gastroenteritis
<i>Giardia lamblia</i>	Protozoa	Diarrhoea
<i>Entamoeba histolytica</i>	Protozoa	Amoebiasis

D. Vector borne transmission

Several infectious diseases are transmitted through vertebrate and non-vertebrate vectors (Table 14). The living transmitters of diseases are called vectors. The vectors may belong to different classes of non vertebrate (insects, ticks, mites, fleas, etc.) and vertebrate (dogs, cats, skunks, bats, etc). The vectors may act in two ways: either carrying the pathogenic organism externally without allowing the pathogen to multiply in their body or carrying the pathogen internally with multiplication of the pathogen in the vector body. The transmission of pathogenic bacteria such as *Salmonella* or *Shiegella* to food by flies contaminated with faecal content is good example of passive/external transfer. However, in the internal transmission the pathogen is carried within the vector. The internal transmission can be classified in to two types (a) harbourage transmission, (b) biological transmission. In case of harbourage transmission there are no morphological or physiological changes in the pathogens within the vector. The good example of this kind of transmission is plague where transmission of *Yersinia pestis* occurs by rat flea to man. In case of biologic transmission, there is morphological or physiological change in the pathogens when it is present in the vector. The pathogen multiplies in vector host and undergoes molecular changes. There are several examples good examples this kind including malarial parasite in mosquito vector, and dengue virus in the insect vector.

Table 14: Important vector diseases

Name of etiologic agent	Type of pathogen	Vector	Disease
Dengue virus	Virus	Mosquito (<i>Aedes aegypti</i> & <i>Aedes albopictus</i>)	Dengue & Dengue haemorrhagic fever
Rabies virus	Virus	Dog, red foxes	Rabies
Flavivirus	Virus	Mosquito (<i>Aedes aegypti</i>)	Yellow fever
<i>Yersinia pestis</i>	Bacteria	Flea (<i>Xenopsylla cheopis</i>)	Plague
<i>Borrelia burgdorferi</i>	Bacteria	<i>Ixodes scapularis</i>	Lyme disease
<i>Ehrlichia chaffeensis</i>	Rickettsia	Lone star tick (<i>Amblyomma americana</i>)	Ehrlichiosis
<i>Plasmodium falciparum</i> <i>P. vivax</i> , <i>P. vivax</i> & <i>P. Malariae</i>	Protozoa	Mosquito (<i>Anopheles</i> spp.)	Malaria
Several species of Leishmania including <i>L. donovani</i> , <i>L. braziliensis</i> , <i>L. mexicana</i>	Protozoa	Sand fly (<i>Phlebotomus</i> spp.)	Leishmaniasis

E. Vehicle transmission

Some bacterial, viral, fungal and parasitic infection can also be transmitted by non living materials. Such materials or objects are called vehicles. The living materials with potential to transmit pathogens include cloths, hospital beddings, surgical instruments, globes, etc. Such objects though carry the pathogens but do not support the proliferation of the pathogens. On face of outbreak of disease these vehicles are called fomites. The contaminated blood or fluids like glucose-saline (for intra venous infusion) can be the source of infection to many patients to whom the blood transfusion or glucose solution is given. In this way food and water may also act as common vehicles to transmit infection to many hosts.

Host -parasite relationship

If an organism either harms or lives at the expense of host, the organism is called ‘parasite’ and this relationship is referred to as parasitism. A variety of parasitic agents including bacteria, viruses, protozoa, helminths, etc have been identified. If the organism resides on the surface of the host, it is called ‘ectoparasite’ where as if it lives internally it is referred to as ‘endoparasite’.

When a microorganism enters into a host, there is interaction between host and the organism. If organism does not cause any harm to the host, a mutually beneficial relationship between microorganism and host is established. However, sometimes the entry of the microorganisms in the host body may result into harmful effects to the host. This results into development of a disease. It has been observed that normal microflora produces chemicals/biochemicals to repel

invading pathogens and prevent them to colonise the host through bacterial interference (also called as bacterial antagonism). The lactobacilli present in genital tract of females maintain low acidic pH and prevent colonisation of pathogens. Similarly *Corynebacteria* present on skin produce acids that prevent colonisation of pathogens on the skin.

Virulence factors

The term virulence refers to the degree of [pathogenicity](#) of a pathogen. It can also be defined as the relative ability of an organism to cause disease. The word virulence has been derived from the Latin word , *virulentus*, which means full of poison'. A wide variety of factors produced by pathogenic organisms including fungi, parasites, bacteria and viruses have been associated with virulence. The virulence factors of pathogenic organisms are generally proteins or other molecules that are synthesized by proteins. These proteins are encoded by genes present in pathogenic organism's chromosomal DNA or viral nucleic acids or plasmids.

The pathogens cause diseases by a wide variety of mechanisms including adhesion, colonization, invasion, immune response inhibition, toxins, etc.

Adhesins

It has been found that certain microorganisms bind to the host cell surface after gaining access to the host. The molecules/structures of the organisms which help in binding with complementary host cell receptors are referred to as 'adhesins'. The adherence of certain pathogens has been found to be necessary for pathogenesis. The adhesins may be located on glycocalyx or other bacterial surface structures such as fimbriae. Majority of adhesins, characterised so far, have been found to be glycoproteins or lipoproteins where as complementary receptors on the host cell surface are generally sugars such as mannose. Different bacteria or even different strains of the same bacterial species may have different types of adhesins. Similarly host cell receptors may also vary. Therefore, either altering adhesins or corresponding host cell receptor, binding of the pathogen may be prevented. This can be illustrated by the example of *Streptococcus mutans*, Gram positive bacterium associated with tooth decay. It attaches to the surface of teeth by glycocalyx glucosyl transferase, an enzyme produced by *S. mutans*, converts glucose into sticky polysaccharide called 'dextran' which forms glycocalyx. *Actinomyces* have fimbriae which attach to glycocalyx of *S. mutans* contributing to the formation of plaques. Similarly enteropathogenic bacteria such as *E. coli* and *Shigella* also have adhesins in their fimbriae to attach to the host cells in the small intestine. *Neisseria gonorrhoeae* (causative agent of gonorrhea) has adhesins on the fimbriae present on the bacterial surface and uses these for the attachment with specific receptors on cells of genitourinary tract. *Treponema pallidum* (the causative agent of syphilis) uses its tapered end as hook to attach to host cells.

Glycocalyx

Literal meaning of glycocalyx is 'sugar coat'. It is composed of either polysaccharide alone or in combination with polypeptides. A sticky and gelatinous polymeric material present on the external surface of bacterial cell wall is known as 'glycocalyx'. Composition of glycocalyx differs in different species of bacteria. Glycocalyx is secreted by bacterial cell. If the glycocalyx is attached on the bacterial cell surface, it is known as 'capsule'.

Capsule

Capsule is formed by glycocalyx around the bacterial cell. In certain bacterial pathogens, it is associated with enhanced virulence. The presence of capsule on bacteria has been linked to decreased phagocytosis in infected host. Chemical composition of capsule prevents attachment of phagocytes to bacterial cells. *Streptococcus pneumoniae* (causative agent of pneumococcal pneumonia) is good example of virulence due to capsule. The mutant strains of *S. pneumoniae* devoid of capsule are having reduced virulence. Similarly capsule plays an important role as virulent factor in *Klebsiella pneumoniae* induced bacterial pneumonia. Capsule has also been found to act as virulence factor in other important bacterial diseases such as anthrax and plague. However, presence of capsule alone may not be sufficient to cause disease as some nonpathogenic bacteria also have capsule.

Fimbriae

A variety of Gram negative bacteria have hair like structures on their surface. These are called 'fimbria' (singular). The number of fimbriae present in each bacterial cell surface is different. The number may vary from a few to hundreds/cell. These help in attachment of bacteria in host cells.

Enzymes

Several enzymes produced by pathogenic organisms have been found to play important role in pathogenesis. These enzymes are produced by bacteria extracellularly, hence called 'exoenzymes'. For example *Helicobacter pylori* is able to survive in the acidic environment of the human stomach by producing 'urease' enzyme. Colonization of the stomach lining by this bacterium can lead to gastric ulcer. The virulence of various strains of *H. pylori* has been correlated with the level of production of urease enzyme. Coagulase is another bacterial enzyme which has been linked to virulence of certain species of bacteria. For example, certain strains *Staphylococcus* produce 'coagulase' enzyme which causes coagulation of blood. Fibrinogen (a plasma protein produced by liver) is converted into fibrin that causes coagulation of blood. However certain strains which do not produce coagulase may still be pathogenic probably due to presence of capsule. Collagenase is another enzyme which acts as virulence factor in some species of *Clostridium*. Collagenase breaks down collagen (a protein that helps in formation of connective tissues of muscle and other body parts). Other enzymes such as hyaluronidase and lecithinase (destroys plasma membrane around blood cells) produced by some species of pathogenic bacteria. Lipases produced by some pathogenic bacteria have also been found act as virulence factors.

Leukocidins

Leukocidins (proteins produced by some bacteria) can destroy white blood cells (WBC). Leukocidins have also been found to inhibit macrophages. It has been observed that leukocidins produced by Streptococci and Staphylococci can degrade lysosomes of leukocytes leading the death of these important cells of immune system.

Haemolysin

These are produced by some pathogenic bacteria. Haemolysins are proteins and are capable of lysing red blood cells (RBCs). Some bacterial species which produce haemolysins are *Clostridium perfringence* (causes gas gangrene) and several species of *Streptococcus*. Haemolysin acts as virulence factor in pathogenesis of haemolysin producing pathogenic organisms.

Toxins

Toxins are poisonous substance produced by some pathogenic microorganisms. These are often main virulence factors contributing to pathogenesis. Either toxins are produced in host body after infection or produced out side. The toxins produced in human food by contaminating microorganisms may cause food poisoning if contaminated foods are consumed. Some of these can remain in "spoiled" food even after cooking and cause illness when the contaminated food is consumed. In general the toxins may cause fever, cardiovascular disturbance, diarrhea, shock, block protein synthesis, destroy blood cells and disrupt nervous system. More than 220 microbial toxins have been characterized so far. The presence of toxin in the blood is referred to as 'toxemia'. The toxins are of two types-endotoxins and exotoxins.

Endotoxins

Endotoxins or lipopolysaccharides are present mainly on cell wall of Gram negative bacteria. Endotoxins are known to activate the host complement pathway and induce inflammation. Endotoxin is composed of three sections viz., a toxic lipid (lipid A) anchored in the outer membrane, an immunogenic polysaccharide core, and an antigenic O-linked series of oligosaccharides at the extracellular surface (Fig. 2). Endotoxins are toxic to most mammals, and can be lethal if encountered in too high a dose. Specifically, release of LPS into the host circulation promotes binding by a certain protein, called "LPS-binding complex". This interacts with CD14 receptors on a variety of monocytes and macrophages, triggering inflammatory cytokine release, and activation of the complement and coagulation cascades. Physiological distress involving pyrogenicity and mitogenicity eventually leads to blood sepsis and death. However, low levels of LPS used, for example, as an adjuvant favourably increases the host's microbial resistance, and induces T-cells to produce more antiviral-enhancing interferon. The Lipid A component of LPS is a strong biological enhancer, and can boost the immune system.

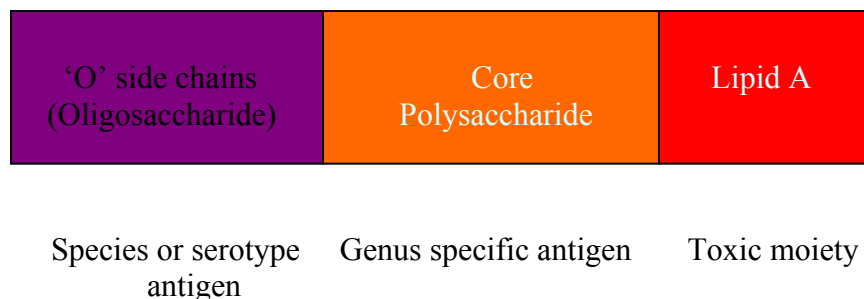


Fig. 2: General structure of endotoxin

Exotoxins

Exotoxins are proteins secreted by pathogenic bacteria. Exotoxins are amongst the most potent toxins known to mankind. Exotoxins are often encoded by plasmids or bacteriophages. A variety of exotoxins produced by a variety of bacterial species have been characterized. General character of the exotoxins includes antigenicity and instability. Most exotoxins are destroyed by heating to 100°C, but some like those of *S. aureus* food poisoning are resistant to boiling. Some toxins can be converted to toxoids which are no longer toxic, but can stimulate antibody production against the toxin. Majority of exotoxins have two subunits viz., A and B (Fig. 3). B subunit is harmless and binds to a host cell receptor where as A subunit is responsible for toxic effect produced by exotoxins. Toxins can also be grouped according to their biological activity in certain cells, such as leukotoxins, neurotoxins, etc.

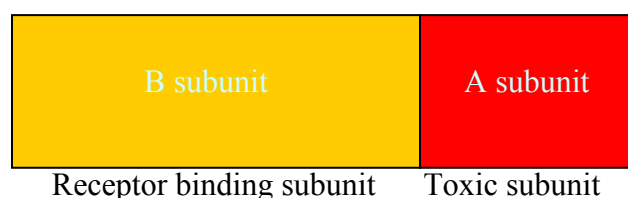


Fig. 3: General structure of exotoxin

Diphtheria exotoxin (DT), produced by *Corynebacterium diphtheriae*, is one of the best studied typical A/B exotoxins. The specific receptor used by B subunit of DT is heparin-binding epidermal growth factor. The A-subunit blocks protein synthesis of the host cell and thus causes cell death. One A-subunit of DT in the cytoplasm is enough to kill. It has been estimated that the bacterium can release up to 5,000 molecules/hour. The bacterium producing this potent toxin grows mainly in the throat. Toxin production only occurs if the bacterium is infected with a certain bacteriophage.

Botulism toxin is another exotoxin which has been extensively studied. It inhibits acetylcholine release from motor nerve endings and kills the nerve cells. This is the most deadly toxin known. Toxin production only occurs if the *Clostridium. botulinum* is infected with a certain bacteriophage (different from the diphtheria toxin). Tetanus toxin is another good example of exotoxins. It blocks the function of certain nerve cells which leads to spastic paralysis in the infected host. *Clostridium. tetani* that produces this toxin is anaerobic and usually grows locally in a puncture wound.

Surface acting exotoxins usually elicit their effects by binding to target cell molecules, or forming membrane pores through which cell lysis occurs. This group includes the vacuolating toxin of *Helicobacter pylori*, *E. coli* hemolysin, and 'superantigens' belonging to *Streptococcus pyogenes* and *Staphylococcus aureus*.

Though the normal microflora of the host prevents invasion or entry of the pathogenic microorganisms, under certain circumstance they can also cause disease in the host. These organisms are then referred to as opportunistic pathogens. The microorganisms normally present in oral cavity do not cause disease. However, if they enter into blood stream due to injury in

mouth, they can cause disease. For example streptococci belonging to viridans which are normally present in mouth, if enter into blood stream after tooth extraction can cause infection of the heart valves.

Infection

The invasion of host by a microorganism with subsequent establishment and multiplication of the agent. An infection may or may not lead to overt disease. However, the infected individual may transmit the infection to other individuals. The infection may be either transitory or it may persist for long time. The infection may be transmitted by any mode as described earlier.

Invasion

The act of entry and subsequent spread of pathogen in the host body tissues is referred to as invasion. The ability of pathogenic organisms to enter host, multiply/reproduce and spread in the host body is called 'invasiveness.'

Pathogenicity

The condition or quality of being pathogenic or the ability to cause disease. Pathogenicity can be defined as the property of any pathogenic agent to cause disease. The severity of the disease depends on the degree of pathogenicity.

Toxigenicity

The capacity of an organism to produce a toxin, chemical substances that will damage the host tissue and produce diseases.

Virulence

The degree or intensity of pathogenicity of an organism as indicated by the case fatality rates and /or ability to invade host tissue and cause disease.

Carrier

An infected individual who is potential source of infection for others and plays an important role in epidemiology of a disease. It has been observed that many people harbour pathogenic organisms and transmit them directly or indirectly to other people. Some individuals may harbour the pathogens without exhibiting signs or illness. These are called carriers. They are important living reservoirs of infection. Human carriers play important roles in transmission of such diseases as hepatitis, diphtheria, typhoid, gonorrhoea, AIDS, amoebic dysentery, etc.

Types of carriers

Four different types of carriers have been identified.

(1) Active carrier

An individual who has an overt case or symptom of clinical disease.

(2) Convalescent carrier

An individual who has recovered from disease but still carries large number of pathogenic organism.

(3) Healthy carrier

An individual who carries the pathogenic organism without exhibiting apparent clinical signs and symptoms.

(4) Incubatory carrier

An individual who is incubating large number of a pathogenic organism but not showing symptoms of illness at this stage, but eventually develops a frank clinical disease. The incubatory carriers have potential to transmit the pathogenic organisms to other individuals.

Suggested Readings

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