Medically important microorganisms

Introduction Microorganisms are classified in groups, the most important of which are the genus and species. Membership of a common group (e.g. genus) implies a certain level of relatedness, or common features. The structural, metabolic, genetic and immunological features of organisms in each successive group are increasingly complex.

Naming microorganisms The names given to medically important micro-organisms usually comprise the genus name, followed by the species name. Either name may contain clues about the organism, the diseases it causes or even its discoverer. Names are usually derived from Latin or Greek and are either underlined or in *italics*. Only the genus name is Capitalised, and its first letter may be used in an abbreviated version e.g.

- *Staphylococcus aureus* (proper name)
- *S. aureus* (proper abbreviated version)
- *Staph. aureus* (colloquial)
- staphylococci (group name)
- *Staphylococcus* sp.

Major categories of microorganism

- bacteria
- fungi
- viruses
- helminths } 'parasites'
- protozoa }

Bacteria

- **single cell organisms with both DNA and RNA, but no defined nucleus. They usually have a cell wall and may possess other features such as pili, fimbriae and flagellae.**

Gram positive cocci e.g. staphylococci, streptococci
Gram positive bacilli e.g. clostridia, *Bacillus* spp.
Gram negative cocci e.g. *Neisseria* spp.
Gram negative bacilli e.g. *Escherichia coli, Pseudomonas* spp., *Haemophilus* spp.
Spirochaetes e.g. *Treponema pallidum, Leptospira* sp.
Vibrios e.g. *Vibrio cholerae*
acid-fast bacilli e.g. mycobacteria, *Nocardia* spp.
actinomyces

Viruses

- **very small organisms that contain either DNA or RNA, and are incapable of propagation outside a living cell**

single stranded DNA viruses e.g. parvoviruses
double stranded DNA viruses e.g. adenoviruses, herpes viruses, papovaviruses, pox viruses
single stranded RNA viruses e.g. bunyaviruses, coronaviruses, orthomyxoviruses, paramyxoviruses, picornaviruses, retroviruses, rhabdoviruses
double stranded RNA viruses e.g. reoviruses
segmented RNA viruses e.g. arenaviruses

Fungi

- **possess DNA and RNA, a defined nucleus and have a cell wall. They are either unicellular (yeasts), filamentous (moulds etc) or dimorphic (both).**

Yeasts e.g. *Candida* sp.
Moulds e.g. *Mucor* sp., *Trichophyton* sp.
Dimorphic e.g. *Histoplasma* sp.
Others e.g. *Pneumocystis jiroveci*

- an alternative classification system is based on clinical syndromes:

superficial mycoses e.g. dermatophytes (*Trichophyton* sp.)
subcutaneous mycoses e.g. *Sporothrix* sp.
systemic/deep mycoses e.g. *Histoplasma* sp.

Parasites

- **a term used to include protozoa; complex unicellular organisms with a defined nucleus and other organelles, and helminths (worms); multicellular organisms. Members of both groups have complex life cycles.**

Protozoa:
Sporozoa, *Plasmodium* sp., *Toxoplasma gondi, Cryptosporidium* sp.
Rhizopoda, *Entamoeba* sp., *Naegleria* sp., m*Acanthomoeba* sp.
Flagellates (intestinal), *Trichomonas* sp., *Giardia intestinalis*
(blood), *Leishmania* sp., *Trypanosoma* sp.

Helminths(worms):
cestodes (flatworms) *Taenia* sp., *Echinococcus* sp.
nematodes (roundworms), *Trichinella* sp., *Ascaris* sp.
trematodes (flukes), (tissue), *Fasciola hepatica*
(blood) *Schistosoma* sp.

Morphology and physiology of microorganisms

Bacteria

Cell wall All bacteria, apart from mycoplasmas, possess a cell wall.
There are three main types of wall structure:
- Gram positive
- Gram negative
- acid fast

The Gram positive cell wall contains a thick layer of peptidoglycan; a sack-like polymer of N-acetyl muramic acid and N-acetyl glucosamine, which gives rigidity to the cell and helps resist changes in osmotic pressure. In the Gram stain, this layer prevents removal of methyl violet stain by organic solvents such as alcohol or acetone. Teichoic acids are also present.

In Gram negative bacteria, the layer of peptidoglycan is much thinner and does not prevent removal of stain by organic solvent . External to the peptidoglycan layer is another layer; a specilised membrane composed of lipoproteins and, on the outer surface, lipopolysaccharides. Their outermost layer is composed of saccharide O chains that vary within bacterial species and are recognised by agglutination with specific antisera (serotypes). In between these two layers is the periplasmic space.

Acid-fast bacteria are highly impermeable to dyes and organic solvents due to a waxy layer in the cell wall. Special staining procedures are required such as the Zeihl-Neelsen method.

Shape Important types of bacterial shape include:

- cocci: spherical
- bacilli: rod, or sausage-shaped
- spirochaetes: thin spirals
- vibrios: comma-shaped

Bacterial shape and Gram stain reaction are used to divide bacteria into major groups e.g. Gram positive cocci and Gram negative bacilli.

Cell membrane In most species the cell membrane is enclosed by the cell wall, however mycoplasmas lack a cell wall and have an exposed cell membrane.

Capsule Some species have a capsule, often composed of polysaccharide, external to the cell wall. This capsule may give some resistance to phagocytosis.

Pili and fimbriae Hair-like structures that protrude from the outer surface of some bacterial species and assist adhesion to external surfaces.

Flagellae Long, thin structures that protrude from the surface of some bacteria and are responsible for producing movement.

Spores Thick-walled structures formed by some species to survive extreme physical conditions.

DNA Bacterial DNA usually takes the form of a single, supercoiled chromosome, and may be accompanied by circular extrachromosomal DNA fragments called plasmids. DNA can be transferred between bacteria in several different ways:

- transformation
- transduction
- conjugation

Transformation involves the uptake of naked bacterial DNA across the cell wall. In transduction, DNA fragments are transferred by viruses called bacteriophages. Conjugation occurs when bacteria transfer DNA along a specialised hollow tube ('sex pilus') connecting the two cells.

Metabolism A variety of nutrients are needed for growth and division. In the laboratory they are provided either in liquid (broth) or solid (broth + agar) form. Also important for growth are ..

- temperature
- gaseous atmosphere
- pH

Growth Most medically important species will grow at or around human body temperature, 37^{o}C; the temperature most commonly used to incubate bacteria from clinical specimens. The gaseous environments used include:

- aerobic: oxygen
- anaerobic: lacks oxygen
- microaerophilic: low oxygen
- capnophilic: carbon dioxide

A few species prefer acidic or alkaline conditions for growth.

When the nutrients available to bacteria are limited (e.g.a broth bottle), growth follows a series of recognised stages :

1. lag phase
2. log phase
3. linear phase
4. plateau phase

Rate of growth under optimal conditions is expressed in terms of doubling time, and ranges from 20 min (*E.coli*) to 18 days (*M.leprae*).

Viruses

Structure Viruses are composed of a nucleic acid, either DNA or RNA, and a coat of protein subunits (or capsomeres) which together form the nucleocapsid. A lipid envelope, and structural

proteins, are found in some species. Viral particles have helical, icosahedral or no regular symmetry. Their nucleic acids may be either single or double stranded, and most are in a linear molecular form.

Growth Viruses are obligate intracellular parasites i.e. they require the metabolic apparatus of a host cell for replication. Many types of virus have a preference or tropism for cells of a particular species or tissue type. Artificially cultivated cells of either primary (finite lifespan) or continuous (immortalised tumour cells) cell type are required for viral culture. Viral growth is usually detected by alterations in the host cells (e.g. change in shape or viability) or by antigen recognition (e.g. immunofluorescence).

Fungi

Fungi can be divided into three main groups with different types of biology:

- yeasts
- moulds
- dimorphic

Structure Fungi have a defined nucleus with both DNA and RNA. They have a complex cell wall that contains sterols. Yeasts are single-cell organisms that reproduce by budding, whereas moulds grow by extending filamentous hyphae. They reproduce asexually by releasing spores from specialised hyphae called conidiophores or sporangiophores. Dimorphic fungi grow in both yeast and mould forms.

Growth Fungi have different nutrient and environmental requirements from bacteria. Most medically important species will grow aerobically on solid media, with a higher carbohydrate content and a lower pH than standard bacteriological agars.

Parasites

The two main groups known to medical microbiologists as 'parasites' are protozoa and helminths. Their complex nutritional requirements and life cycles mean that laboratory culture is only possible in rare cases. However, their microscopic appearance is also more complex and has therefore been used to identify them.

Organisms that can confuse

Mycoplasmas: small bacteria that lack a cell wall but can be cultivated on cell-free media
Chlamydias: small, energy dependant bacteria that are obligate intracellular parasites and will only grow in cell culture
Rickettsias: small bacteria that are also obligate intracellular parasites
Prions: self replicating proteins that may have a role in some slow virus diseases