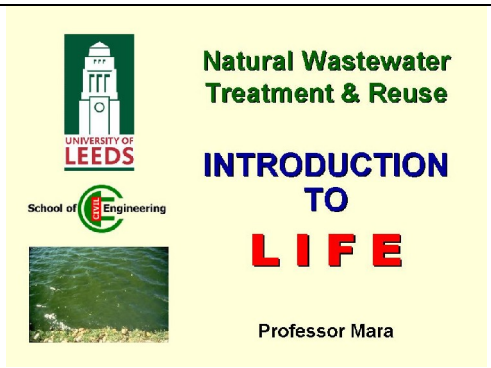
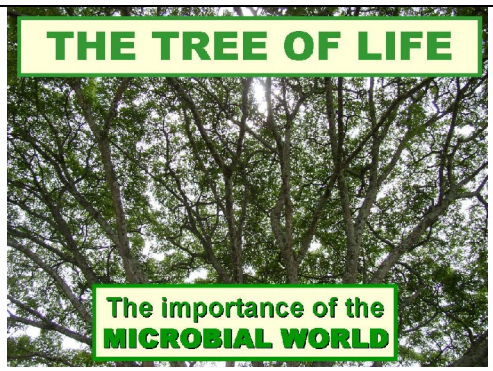
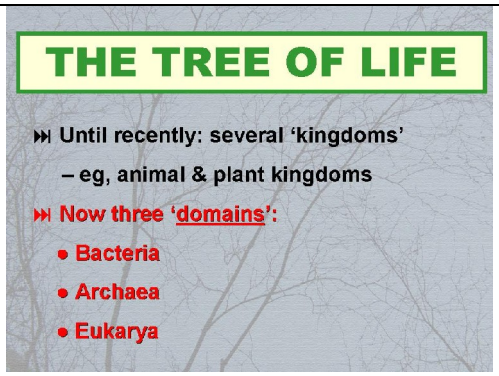
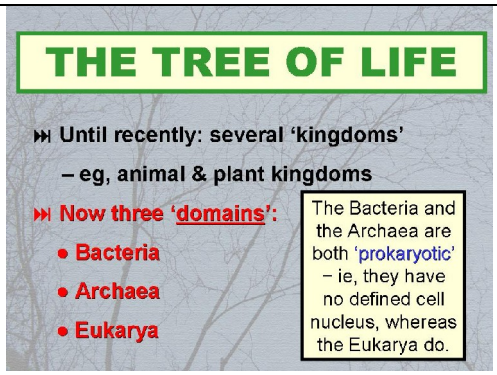
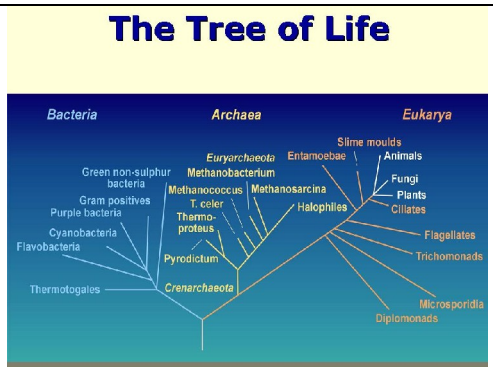
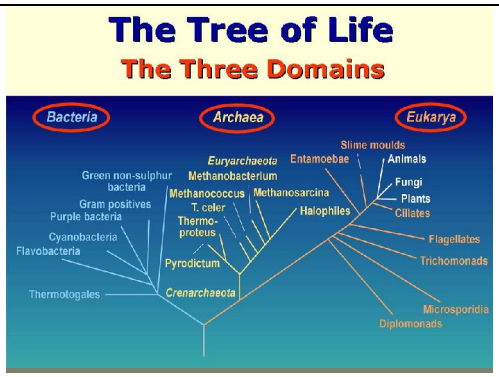
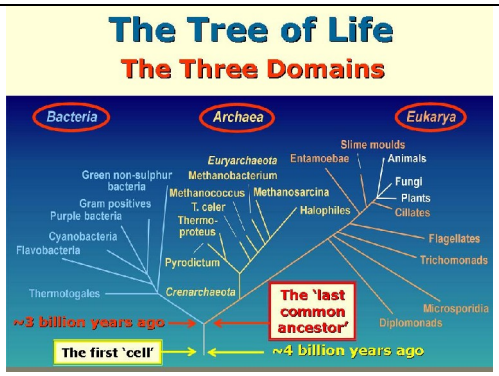
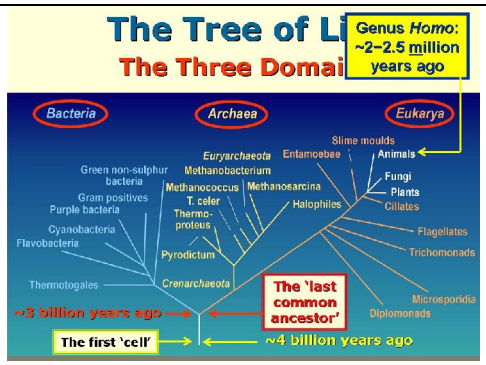
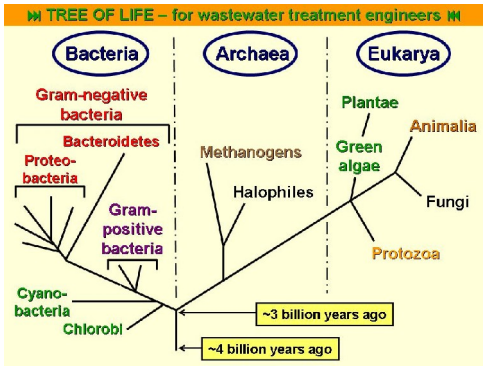
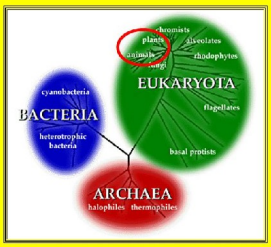
An Introduction to Life

1.		This presentation is an Introduction to Life, specifically the forms of Life involved in wastewater treatment,
2.		and these life forms are all, or almost all, **microbial**, and what we generally refer to as 'biological wastewater treatment' is actually *microbiological* wastewater treatment and the processes occurring in this type of treatment plant rely on microbial activity. So we need to know at least something about these micro-organisms which treat our wastewaters. Microbes are the most numerous, the most diverse and, perhaps with us, the most dominant form of Life on Earth; and all life forms have evolved from microbes.
3.		So we're going to look at the Tree of Life and we'll see how important the microbial world is.
4.		Until fairly recently we divided Life into Kingdoms – for example, the plant and animal kingdoms, with which, I guess, you're familiar. However, evolutionary biologists now consider Life in three **Domains**: the Bacteria, the Archaea and the Eukarya, all with capital initial letters. The Bacteria and the Archaea comprise what we generally refer to as 'bacteria' with a small 'b'.

5.		The Bacteria and the Archaea are both 'prokaryotic', which is to say they have no defined cell nucleus. The Eukarya, on the other hand, do.
6.		This is a schematic of the Tree of Life from an evolutionary biologist's perspective. It's somewhat complex, but at least …
7.		we can straightforwardly see the three Domains − the Bacteria, the Archaea and the Eukarya.
8.		Looking at the bottom of the slide, we can see two important events: first, about 4 billion years ago the first 'cell' or independent life form, appeared; and second, about 3 billion years ago, there was the so-called 'last common ancestor' from which after this time the three Domains started to evolve.

9.		We belong to the Animalia, and our genus, *Homo*, only started to appear ~2–2.5 *million* years ago, so we're very recent newcomers to planet Earth.
10.		This is a version of the Tree of Life for wastewater treatment engineers, and we're now going to consider important groups in the three Domains that are especially relevant to us as wastewater treatment engineers.
11.	**The Bacteria** ➢ **Gram-positive and Gram-negative bacteria** – originally just a cell staining procedure (devised by Hans Christian Gram, a Danish bacteriologist, in 1884) ➢ Now known that Gram +ve and Gram −ve bacteria differ in a much more fundamental way: ▪ Gram +ves have a single-membrane cell wall ('monoderms') ▪ Gram −ves have a double-membrane cell wall ('diderms')	First of all the Domain **Bacteria**. One common way of dividing the Bacteria is into Gram-positive and Gram-negative bacteria. Originally this was a cell staining procedure devised by a Danish bacterio-logist called Hans Christian Gram, way back in 1884; but we now know that Gram-positive and Gram-negative bacteria differ in a much more fundamental and genetic way. The Gram-positives are 'mono-derms', that is to say they have a single-membrane cell wall, and the Gram-negatives are 'diderms' and have a double-membrane cell wall.
12.	**Gram-negative bacteria** • Main group of Gram-neg. bacteria is the **Proteobacteria**, which comprise (at present) five classes [α–ε]. • For wastewater treatment engineering: (a) **Chemoheterotrophs** (obtain cell C from organic cpds) – *extremely important!* .... (b) Chemo-autotrophs (obtain cell C from CO_2) – eg, **nitrifiers** [$NH_3 \rightarrow NO_2 \rightarrow NO_3$] (c) Purple bacteria; some Green sulphur bacteria (eg, Chromatiaceae) ***Note:*** *(c) above are photosynthetic bacteria – see the presentation Purple Ponds for details of bacterial photosynthesis.*	The main group of Gram-negative bacteria is the Proteobacteria and these are currently classified in five classes, α–ε. From our point of view as wastewater treatment engineers, three general groups of the Proteobacteria are important. First, the **chemoheterotrophs** which get the carbon they need to make their cells from organic compounds, and we'll talk more about them in a moment. Then there are the **chemo-autotrophs** and these get their cell carbon from dissolved CO_2; an important group of chemo-autotrophs is the nitrifiers which oxidize ammonia to nitrite and then

	Gram-negative bacteria • Main group of Gram-neg. bacteria is the **Proteobacteria**, which comprise (at present) five classes [α–ε]. • For wastewater treatment engineering: (a) **Chemoheterotrophs** (obtain cell C from organic cpds) – *extremely important!* .... (b) Chemo-autotrophs (obtain cell C from CO_2) – eg, **nitrifiers** [$NH_3 \rightarrow NO_2 \rightarrow NO_3$] (c) Purple bacteria; some Green sulphur bacteria (eg, Chromatiaceae) [Slide repeated for clarity]	to nitrate. And thirdly there is a group of photosynthetic bacteria, including the purple bacteria and some green bacteria.* **See the presentation 'Purple Ponds' for details of bacterial photosynthesis.*
13.	**Chemoheterotrophs** This very important and diverse group includes: ▪ the Enterobacteriaceae – *Escherichia coli,* faecal & non-faecal coliforms, salmonellae, shigellae; also vibrios, campylobacters..... ▪ almost all the aerobic/facultative bacteria of wastewater treatment (the 'BOD removers') ▪ some important anaerobes – eg, sulphate-reducing bacteria All the above are Proteobacteria. ▪ The Bacteroidetes (the other main Gram-neg. group) contains the Cytophaga–Flavobacterium complex – also common aerobic aquatic chemoheterotrophs ***Note:*** *see the presentations on Water- and Excreta-related Communicable Diseases for information on bacterial pathogens.*	The chemoheterotrophs are a very important and diverse group, including the family Enterobacteriaceae, and this is a hugely important family as it contains *E. coli*, faecal and non-faecal coliforms, salmonellae, shigellae, vibrios and campylobacters. Almost all the aerobic and facultative bacteria of wastewater treatment, the 'BOD removers' are chemheterotrophs, as are some important anaerobes – for example, many of the sulphate-reducing bacteria. The chemoheterotrophs that we've mentioned so far are Proteobacteria. The other main Gram-negative group, the Bacterioidetes, contains the *Cytophaga-Flavobacterium* complex and these are also common aquatic chemoheterotrophs.
14.	**Gram-positive bacteria** Two groups, including: ▪ *Bacillus, Clostridium* (spore-formers) ▪ *Streptococcus, Enterococcus* ('faecal streps') ▪ *Desulfotomaculum* (thermophilic sulphate-reducer) **Other important bacterial groups** ▪ Cyanobacteria ('blue green algae') ▪ Chlorobi These two are photosynthetic Bacteria	The Gram-positives are in two groups, but we don't need to know this level of detail. Suffice it to say that, among the Gram-positives, are the genera *Bacillus* and *Clostridium*, with the former being aerobic and the latter anaerobic, and the clostridia are also spore-formers. The so-called 'faecal streps', members of the genera *Streptococcus* and *Enterococcus*, are Gram-positive; as are members of the genus *Desulfotomaculum*, which are thermophilic sulphate-reducing bacteria. There are other important groups in the Bacteria – for example, the cyanobacteria and the Chlorobi, which are both photosynthetic.

15.	**The Archaea** • Gram-positive • Typically live in 'extreme' environments (eg, very hot, very salty, very acid, anaerobic) • Includes the various genera of anaerobic methanogens of anaerobic wastewater treatment (eg, septic tanks, anaerobic ponds) • also 'halophiles' (eg, marine microbes – important when wastewater from coastal towns and cities discharged into the sea)	Now the Domain **Archaea** All Archaea are Gram-positive. They typically live in 'extreme' environments − for example, where it's very hot, or very salty, or very acid, and often where there's no oxygen. They include the methanogens, the microbes that produce methane, CH_4, so they're in septic tanks, anaerobic ponds and anaerobic sludge digesters. They also include the halophiles or salt-lovers − marine bacteria, for example, and these are important if we discharge raw or treated wastewater into the sea.
16.	**The Eukarya** • **Green algae** − the 'workhorses' of WSP • **Protozoa** − several important human pathogens [Some evolutionary biologists group these two (+ others) in the kingdom **Protista**, or just call them **protists**. Some consider the green algae as Plantae.] • **Plantae** − the plants used in constructed wetlands ("reedbeds") • **Animalia** − the pathogenic helminths ***Note:*** *see the presentations on Water- and Excreta-related Communicable Diseases for information on these pathogen groups.*	The third Domain, the **Eukarya**, has some members that are important in wastewater treatment. For example: the **green algae**, which are the 'workhorses' of waste stabilization ponds; some **protozoa** are serious human pathogens and some non-pathogenic groups are important in activated sludge; in the Plantae there are the various **plants** grown in constructed wetlands, generally reeds and rushes; and in the Animalia there are the pathogenic **helminths** which cause a range of chronic infections in poor communities in developing countries.
17.	And finally: **Bacterial diversity**  **The Bacteria are *very* diverse** – for example: Cyanobacteria and Proteobacteria are *less* closely related to each other than are Animalia and Plantae	Finally, a word on **diversity** in the Domain Bacteria. There is enormous diversity throughout this Domain − for example, the cyanobacteria and the Proteobacteria are *less* closely related to each other than are plants and animals, strictly the Plantae and the Animalia, the two main kingdoms we used to group all life into. Put another way, we're closer, genetically, to a flowering plant, or an oak tree, than cyanobacteria are to Proteobacteria.