Genetic exchange

In addition to mutations, bacteria can alter their genetic make-up by transferring information from one cell to another, either as fragments of DNA or in the form of small extrachromosomal elements (plasmids). Transfer can be achieved in three ways: by transformation, transduction or conjugation.

Transformation. When bacteria die they lyse and release cell fragments, including DNA, into the environment. Several bacterial genera (*Bacillus, Haemophilus, Streptococcus*, etc.) are able to take up these DNA fragments and incorporate them into their own chromosome, thereby inheriting the characteristics carried on that fragment. Cells able to participate in transformation are called competent. The development of competence has been shown in some cases to occur synchronously in a culture under the action of specific inducing proteins.

Transduction. Some bacteriophages infect a bacterial cell and incorporate their nucleic acid into the host cell chromosome, with the result that the viral genes are replicated along with the bacterial DNA. In many instances this is a dormant lysogenic state for the phage but sometimes it is triggered into action and lysis of the cell occurs with liberation of phage particles. These new phage particles may have bacterial DNA incorporated into the viral genome and this will infect any new host cell. On entering a new lysogenic state, the new host cell will replicate the viral nucleic acid in addition to that portion received from the previous host. Bacteria in which this has been shown to occur include *Mycobacterium, Salmonella, Shigella* and *Staphylococcus*.

Conjugation. Gram-negative bacteria such as *Salmonella, Shigella* and *Escherichia coli* have been shown to transfer genetic material conferring antibiotic resistance by cellular contact. This process is called conjugation and is controlled by an R-factor plasmid, which is a small circular strand of duplex DNA replicating independently from the bacterial chromosome. R factor comprises a region containing resistance transfer genes that control the formation of sex pili, together with a variety of genes that code for the resistance to drugs. Conjugation is initiated when the resistance transfer genes stimulate the production of a sex pilus and random motion brings about contact with a recipient cell. One strand of the replicating R factor is nicked and passes through the sex pilus into the recipient cell. Upon receipt of this single strand of plasmid DNA, the complementary strand is produced and the free ends are joined. For a short time afterwards this cell has the ability to form a sex pilus itself and so transfer the R factor further.

This is by no means an exhaustive discussion of genetic exchange in bacteria and the reader is referred to the bibliography for further information.

Bacterial nutrition

Bacteria require certain elements in fairly large quantities for growth and metabolism, including carbon, hydrogen, oxygen and nitrogen. Sulphur and phosphorus are also required but not in such large amounts. Only low concentrations of iron, calcium, potassium, sodium, magnesium and manganese are needed. Some elements, such as cobalt, zinc and copper, are required only in trace amounts and an actual requirement may be difficult to demonstrate.

The metabolic capabilities of bacteria differ considerably and this is reflected in the form in which nutrients may be assimilated. Bacteria can be classified according to their requirements for carbon and energy.

Lithotrophs (synonym: autotrophs). These utilize carbon dioxide as their main source of carbon. Energy is derived from different sources within this group:

- chemolithotrophs (chemosynthetic autotrophs) obtain their energy from the oxidation of inorganic compounds
- photolithotrophs (photosynthetic autotrophs) obtain their energy from sunlight.

Organotrophs (synonym: heterotrophs). Organotrophs utilize organic carbon sources and can similarly be divided into:

- chemoorganotrophs, which obtain their energy from oxidation or fermentation of organic compounds
- photoorganotrophs, which utilize light energy.

Oxygen requirements

As mentioned above, all bacteria require elemental oxygen in order to build up the complex materials necessary for growth and metabolism, but many organisms also require free oxygen as the final electron acceptor in the breakdown of carbon and energy sources. These organisms are called aerobes. If the