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QUESTION

1. Discuss microbial variation and hereditary in bacteria
2. Explain microbial recombination

**MICROBIAL VARIATION AND HEREDITARY IN BACTERIA**

The diversity of form and function among microorganisms is unparalleled among other groups of organisms. Microorganisms exhibit an enormous capacity to evolve new potentialities. This is associated with a:

1. Relatively undifferentiated soma in which all or most nuclei are potentially germinative rather than somatic.
2. Short generation time
3. Manifold means of variation
4. Existence of a haploid vegetative phase allowing expression of recessive genes.

Variation refers to change in an organism, relative to its parent or former state. From the viewpoint of the industrial microbiologist, only the expressed change in appearance or function -the phenotype- is of interest. However, even latent changes in the gene pattern, the genotype may have evolutionary significance. Visual changes at the cellular level in turn reflect changes in the genes or cytoplasm. Thus, differences in phenotype between different organisms grown under identical conditions would, in general, be accounted for by a difference in genes present. However. the absence of expressed differences does not prelude differences in genotype.

**FORMS OF MICROBIAL VARIATION**

There are two forms of variation;

1. Environmental variation
2. Hereditary variation

This classification is defendant on whether the change results from interplay of gene and environment, or from the introduction of new genes (by intra-change or inter-change). Since heredity is the transfer of genes, hereditary (gene) variation is transmissible to the progeny. Environmental variation by definition does not alter the genes, and is therefore considered non transmissible.

**ENVIRONMENTAL VARIATION**

Structurally and functionally, a microbial cell is composed of genes (or nucleus containing genes) and a surrounding cytoplasm. The genes have been described ascites on bipartite deoxyribonuc1eic acid (DNA) **chain**. As cellular determinants, the genes apparently leave their imprint on a ribonuc1eic acid (RNA) chain, which passing to the cytoplasm, acts as a template for the polymerization of activated amino acids into enzyme molecules. The enzymes, thereby synthesized under gene control, mediate the activities of the cello

In considering environmental variation, the environment may be pictured as controlling the level of expression within the range permitted by the gene, by reacting directly or indirectly with the gene in a reversible physicochemical reaction. Since the immediate environment of the gene is the cytoplasm, environmental stimuli originating outside the cell may be modified here. A change in pH level of the medium, for example, could alter solubility of metabolites, membrane permeability, enzyme activity through dissociation of enzyme-substrate complexes, equilibria, hydrogen bonding, etc. These effects in turn would trigger other reactions or reaction sequences. The effected changes cease when equilibrium is restored in the reaction between gene and environmental reactant.

Environmental stimuli inc1ude response to specific medium constituents and their concentration, pH, temperature, moisture, light, aeration, etc. Time may be looked upon as an environmental factor, in that it allows accumulation of metabolites, and wear and tear, resulting perhaps in maturation. Differentiation of cells of presumably identical heritage could reflect local threshold concentrations of metabolites resulting from differences in time of exposure or distance from stimuli.

Those engaged in fermentation have noted that an organism's past environmental history may markedly affect the future course of development of the culture--in the absence of any demonstrable change in its heredity. There is no transfer of acquired characters, since the new traits are seldom permanent. A plausible hypothesis for which evidence would be welcome is presented here. Namely, carryover of mitochondria, microsomes, and enzyme molecules with high turnover could have significant activity, though diluted extensively in con-centration by growth and cell division. It is the transfer of such substances, rather than the gene pattern to which it bears semblance, that is operative in these instances. In all cases, however, the perpetuation of this pattern depends ultimately on replication and carryover of the genes.

When the environmental stimulus seems to have a directed effect in the elaboration of an enzyme not normally produced, the latter is said to be an adaptive or induced enzyme. It is conceivable that the so-called constitutive enzymes are induced by endogenously formed metabolites. The sum total of responses or changes the organism undergoes in approaching a new equilibrium in a new environment is adaptation. Environmental variation is only one facet of adaptation, since the range of ability to adapt, which is gene-controlled, is also subject to variation.

**HEREDITARY VARIATION**

Unlike environmental variation in which the reaction of the environmental stimulus with the gene or an intermediary is a reversible one, hereditary variation may be hypothesized to be an irreversible reaction directly involving the gene. Since the self-replicating gene is affected, and is also transferable, this type of variation tends to be perpetuated.

Hereditary variation can occur in microorganisms by;

1. Mutation
2. Recombination

**MUTATION**

Mutation is a stable inherited change in the properties of a microorganisms (morphological, cultural, biochemical, biological, etc), which is not associated with the recombination process. Mutation which occurs in the nucleoid and is determined by definite region (nucleotide) of the DNA molecule and cytoplasmic mutation I.e inherited changes which take place in the cytoplasm and are transmitted by the cytoplasmic structures, are distinguished.

Mutations may be attended with the loss (deletion) or addition ( duplication) of one base or a small group of bases in the DNA molecule as well as the changes in the sequence of DNA nucleotide.

Bacterial mutations may be

1. Spontaneous: occurring under the influence of external factors without interference of an experimental
2. Induced: developing due to treatment of microbial population with mutagens (radiation, temperature, chemical , and other factors).

There are large and small (point) mutations. The large reorganization include mutation characterized by a deletion of a large area of gene. Point mutation takes place within the gene itself and consists in the replacement, inclusion, or deletion of one pair of DNA nucleotide. Large mutations are attended with breaks in the poly nucleotide chains leading to disintegration of all systems of the bacterial cell. Spontaneous and induced reversion resulting in the restoration of the lost trait may occur in point mutations, where as large mutations is lethal as a rule.

Damages to the DNA structure due to the effect of ultraviolet light and various chemical compounds may be corrected by the means of the systems of reparation; it comprises of a complex of enzymes which detects the damage, cuts out the damaged area of the nucleotide strand and replace it by a complementary undamaged strand. Reparative processes may also be effected by recombination replacement of the damaged area by an undamaged area.

The vast majority of mutations would be expected to be undesirable, in that the organism has over a period of time adapted to its environment. Sudden changes in the genes would throw the organism out of equilibrium. Only a minute fraction of the random mutations that occur could be expected to be desirable from either the standpoint of the organism or the investigator. The cause of spontaneous mutation is not known. Certainly wear and tear, and cumulative cosmic radiation among others, cannot be ignored. Inherent differences in mutability between genes may reflect their relative exposure and ability to withstand such stress. This in turn is a function of the location of the gene (its chemical environment) and its chemical nature.

**RECOMBINATION**

Hereditary variation of a sexual nature can occur by recombination of genes from haploid nuclei to form a diploid heterozygote. Recombinant types, somewhat limited by linkage, are partially restored by crossing-over.1f the organism possesses a haploid stage, variation may occur upon segregation. Recombination can occur in three ways;

In transformation, some bacteria have evolved systems that transports free DNA from the outside of the bacteria cell into the cytoplasm. These bacteria are called “naturally competent” for DNA transformation.

Transduction is the transfer of DNA from one bacterium to another by means of bacteria infecting virus called a bacteriophage.

phage carries genetic information, apparently single genes, from the cell of one strain to another. The transferred genes become part of the genotype of the receptor cell.

Conjugation refers to the transfer of DNA between bacteria cells that require cell to cell contact.

The above instances of hereditary variation concern the nuclear genes. In certain organisms containing the normal complement of nuclear genes, other particulate matter in the cytoplasm has been found to control certain characters, analogous to nuclear genes. These particles are also mutable and self-replicating and also transmissible

**EXAMPLES OF MICROBIAL VARIATION**

Variation in the main characters of microorganisms

1. CHANGES IN MORPHOLOGICAL CHARACTERS :

Under the influence of chemical, and physical effects, some cells can form of large spheres, thickened filaments, flask-shaped formations and branching resembling fungal mycelia. Glamelia observed morphological changes in a number of microbes e.g formation of giant spheres, amoeboid forms, thickened filaments e t.c . He named this phenomenon heteromorphism that arises due to the adaptation of bacteria to unusual environmental conditions.

Heteromorphism easily occurs under the influence of lithium salt, phage, sulphanamides, antibiotics, different types if irradiation and also many other factors. The phenomenon is relatively often observed in the old culture of microorganisms

The affinity for dyes, formation of flagella, cilia, spores and the structure of Hereditary apparatus are also subject to the variation. It should be noted that any change in morphological features is attended with a change in physiological properties too. Therefore the subdivision of the types of bacteria variation into morphological, cultural, enzymatic, biological etc. Is conventional and mainly for more discussion of the multiform material on the subject.

1. CHANGES IN CULTURAL PROPERTIES

Besides morphological deviations in microbes,changes are often observed in cultural practices. Many scientists established that the culture of one and the same species of bacteria may differ among themselves. When a pure culture is seeded into a solid nutrients medium,different forms of colonies of two main types are produced ; smooth-- the S form and rough – the R form. Between thiese two types of colonies, there are transitional, unstable form and more often O forms. The difference between S and R form is not only limited to the forms of colonizes but includes other characters. This kind of variatiom is known as dissosiation.

1. VARIATION IN REQUIREMENTS IN METABOLITES

Under the influence of antibiotics and chemotherapeutic substances, x-rays, ultraviolet radiation, irradiations and other effects. In some microbes the need for certain amino acids and growth factors appears which the original culture did not require. This variations which for their development require special conditions are known as autotrophic in contrast to the original strain phototropic

1. VARIATIONS IN ENZYMATIC FUNCTIONS

Variations in microbes is not limited to the morphology, size or cultural characteristics but includes other properties. Of special theoretical and practical interest is the variation of enzymatic activity in bacteria and their adaptation to the changed internal and external environmental conditions. The addition of a definite substance to the medium may cause activation of the enzyme which had been in a latent phase.

The catalytic activity of bacteria can be increased many times by adding substrate inducing the synthesis of enzymes in the corresponding conditions of cultivation (certain amount of vitamins, definite pH level and degree of aeration). By the addition of certain toxic substances on bacteria it is possible to deprive them of their ability to produce various enzymes.

1. VARIATION OF BIOLOGICAL PROPERTIES

A rather important circumstance is that in a pathogenic microbes under the effect of different factors, the degree of pathogenicity is altered. The decrease in pathogenicity of a microbe while retaining the ability to cause immunity was genetics of microbes noticed long ago. According to this principal, but with different modifications, altered forms of pathogenic forms of microbes that were obtained named at first attenuated (weakened) and then live vaccines.

Viruses, like bacteria under the effect of different factors (hydroxylamine, bromine substituted bases, rise in temperature, drop In medium pH etc) are able to lose their pathogenicity party or completely and retain their immunologic properties. Modern method of preparing vaccines against a number of viral diseases are based on this principal.

**HEREDITARY IN BACTERIA**

The characteristics of the parent can be inherited by the progeny. As stated above, they are 2 types of variations but only the heritable variation I.e mutation and recombination can be inherited by the offspring or the new form.

There are two ways by which this characteristics are inherited

1. Vertical transfer
2. Horizontal transfer

**VERTICAL TRANSFER**

This is the transfer of genetic material from mother cell to offspring I’m the same population. Occasionally, a spontaneous genetic change occurs in one of the cells. This change (mutation) is heritable and passed on to the progeny of the variant cell to produce a subclone with characteristics different from the original (wild type) parent. This is termed vertical inheritance.

If the change is detrimental to the growth of the cell, the subclone will quickly be overrun by the healthy, wild type population. However, if the change is beneficial, the subclone may overtake the wild type population. This is an example of how evolution is directed by natural selection.

Spontaneous mutations are of two classes:

1. Point mutation, or change of a single nucleotide and
2. DNA rearrangement, or shuffling of the genetic information to produce insertions, deletions, inversions, or changes in structure.

DNA rearrangements can affect a few to several thousand nucleotides. Both types of mutations generally occur at a low frequency (roughly once in 106 to 108 cells for any particular gene) and lead to a continuous, slow evolution of bacterial populations.

**HORIZONTAL TRANSFER**

Bacterial variation can also occur by horizontal transfer of genetic material from one cell to another of different populations. Consider two cells from different populations: bacterium B has features distinct from those of bacterium A. There are three possible mechanisms for transferring a trait from B to A:

(1) Transformation : release and uptake of naked DNA

(2) Transduction :packaging and transfer of bacterial DNA by viruses

(3) Conjugation : bacterial mating in which cells must be in contact.

For all three process, the transferred DNA must be stably incorporated into the genetic material of the recipient bacterium. This can occur in two ways:

(1) recombination, or integration of the transferred DNA into the bacterial chromosome

(2) establishment of a plasmid, i.e., the transferred material essentially forms a mini chromosome capable of autonomous replication.

Variation and Hereditary work together to accelerate the rate of bacterial evolution. The spontaneous changes required to produce a new function (e.g. antibiotic resistance) may occur at a low frequency. However, once the function has developed, it can readily spread to other bacterial populations. The limitation is the probability and efficiency of gene exchange between different bacteria. Under certain conditions, gene exchange is very efficient.

**MICROBIAL RECOMBINATION**

Microorganisms have the ability to acquire genes and there by undergo the process of recombination. In recombination, a new chromosome with a genotype different from that of the parent results from the combination of genetic material of two organisms. These new arrangement of genes, is usually accompanied by chemical or physical properties.

In microorganisms, several kinds of recombination are known to occur. The most common form is **general recombination**, which usually involves a reciprocal exchange of DNA between a pair of DNA sequences. It occurs anywhere on the microbial chromosome and is typified by the exchanges occurring in bacterial transformation, bacterial recombination and bacterial transduction.

A second type of recombination, **called site specific combination,** involves the immigration of a viral genome into the bacterial chromosome. A third type is  **replicative recombination**, which is due to the movement of genetic element as they switch position from one place on the chromosome to another.

The principles of recombination apply to prokaryotic microorganisms but not to eukaryotic microbes. Eukaryotes exhibit a complete sexual life cycle including meiosis. In this process, new combinations of a particular gene form during the process of crossing over. This process occurs between homologous chromosomes and is not seen in bacteria, where out a single chromosome exist. Much of the work in microbial genetics has being performed with bacteria and unique features of microbial genetics are usually those associated with prokaryotes such as bacteria.

Thus, we would look further into bacteria recombination as a specific example

**BACTERIA RECOMBINATION**

Bacteria do not have an obligate sexual reproductive stage in their life cycle, but they can be very active in the exchange of genetic information. The genetic information carried in the DNA can be transferred from one cell to another; however, this is not a true exchange, because only one partner receives the new information. In addition, the amount of DNA that is transferred is usually only a small piece of the chromosome.

There are three mechanisms by which this takes place;

1. TRANSFORMATION

In transformation , bacteria take up free fragments of DNA that are floating in the medium. To take up the DNA efficiently, bacterial cells must be in a competent state, which is defined by the capability of bacteria to bind free fragments of DNA and is formed naturally only in a limited number of bacteria, such as Haemophiliac, Neisseria, Streptococcus, and Bacillus. Many other bacteria, including E. coli, can be rendered competent artificially under laboratory conditions, such as by exposure to solutions of calcium chloride (CaCl2). Transformation is a major tool in recombinant DNA technology because fragments of DNA from one organism can be taken up by a second organism, thus allowing the second organism to acquire new characteristics.

1. TRANSDUCTION

Transduction is the transfer of DNA from one bacterium to another by means of a bacteria-infecting viruses called a bacteriophage. Transduction is an efficient means of transferring DNA between bacteria because DNA enclosed in the bacteriophage is protected from physical decay and from attack by enzymes in the [environment](https://www.merriam-webster.com/dictionary/environment) and is injected directly into cells by the bacteriophage. However, widespread gene transfer by means of transduction is of limited significance because the packaging of bacterial DNA into a virus is inefficient and the bacteriophages are usually highly restricted in the range of bacterial species that they can infect. Thus, interspecies transfer of DNA by transduction is rare.

1. CONJUGATION

Conjugation is the transfer of DNA by direct cell-to-cell contact that is mediated by plasmids (non chromosomal DNA molecules). Conjugative plasmids encode an extremely efficient mechanism that mediates their own transfer from a donor cell to a recipient cell. The process takes place in one direction since only the donor cells contain the conjugative plasmid. In gram-negative bacteria, donor cells produce a specific plasmid-coded pilus, called the sex pilus, which attaches the donor cell to the recipient cell. Once connected, the two cells are brought into direct contact, and a conjugal bridge forms through which the DNA is transferred from the donor to the recipient. Many conjugative plasmids can be transferred between, and reproduce in, a large number of different gram-negative bacterial species. Plasmids vary in size, from a few thousand to more than 100,000 base pairs; the latter are sometimes called megaplasmids.

The bacterial chromosome can also be transferred during conjugation, although this happens less frequently than plasmid transfer. Conjugation allows the inheritance of large portions of genes and may be responsible for the existence of bacteria with traits of several different species. Conjugation also has been observed in the gram-positive genus, Enterococcus, but the mechanism of cell recognition and DNA transfer is different from that which occurs in gram-negative bacteria.