Bacteria can plan ahead

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Bacteria can anticipate a future event and prepare for it, according to new research at the Weizmann Institute of Science. In a paper that appeared today in *Nature*, Prof. Yitzhak Pilpel, doctoral student Amir Mitchell and research associate Dr. Orna Dahan of the Institute's Molecular Genetics Department, together with Prof. Martin Kupiec and Gal Romano of Tel Aviv University, examined microorganisms living in environments that change in predictable ways.

Their findings show that these microorganisms' genetic networks are hard-wired to 'foresee' what comes next in the sequence of events and begin responding to the new state of affairs before its onset.

E. coli bacteria, for instance, which normally cruise harmlessly down the digestive tract, encounter a number of different environments on their way. In particular, they find that one type of sugar - lactose - is invariably followed by a second sugar - maltose - soon afterward. Pilpel and his team of the Molecular Genetics Department, checked the bacterium's genetic response to lactose, and found that, in addition to the genes that enable it to digest lactose, the gene network for utilizing maltose was partially activated. When they switched the order of the sugars, giving the bacteria maltose first, there was no corresponding activation of lactose genes, implying that bacteria have naturally 'learned' to get ready for a serving of maltose after a lactose appetizer.

Another microorganism that experiences consistent changes is wine yeast. As fermentation progresses, sugar and acidity levels change, alcohol levels rise, and the yeast's environment heats up. Although the

system was somewhat more complicated that that of *E. coli*, the scientists found that when the wine yeast feel the heat, they begin activating genes for dealing with the stresses of the next stage. Further analysis showed that this anticipation and early response is an evolutionary adaptation that increases the organism's chances of survival.

Ivan Pavlov first demonstrated this type of adaptive anticipation, known as a conditioned response, in dogs in the 1890s. He trained the dogs to salivate in response to a stimulus by repeatedly ringing a bell before giving them food. In the microorganisms, says Pilpel, 'evolution over many generations replaces conditioned learning, but the end result is similar.' 'In both evolution and learning,' says Mitchell, 'the organism adapts its responses to environmental cues, improving its ability to survive.' Romano: 'This is not a generalized stress response, but one that is precisely geared to an anticipated event.' To see whether the microorganisms were truly exhibiting a conditioned response, Pilpel and Mitchell devised a further test for the *E. coli* based on another of Pavlov's experiments. When Pavlov stopped giving the dogs food after ringing the bell, the conditioned response faded until they eventually ceased salivating at its sound. The scientists did something similar, using bacteria grown by Dr. Erez Dekel, in the lab of Prof. Uri Alon of the Molecular Cell Biology Department, in an environment containing the first sugar, lactose, but not following it up with maltose. After several months, the bacteria had evolved to stop activating their maltose genes at the taste of lactose, only turning them on when maltose was actually available.

'This showed us that there is a cost to advanced preparation, but that the benefits to the organism outweigh the costs in the right circumstances,' says Pilpel. What are those circumstances? Based on the experimental evidence, the research team created a sort of cost/benefit model to predict the types of situations in which an organism could increase its chances of survival by evolving to anticipate future events. They are

already planning a number of new tests for their model, as well as different avenues of experimentation based on the insights they have gained.

Pilpel and his team believe that genetic conditioned response may be a widespread means of evolutionary adaptation that enhances survival in many organisms - one that may also take place in the cells of higher organisms, including humans. These findings could have practical implications, as well. Genetically engineered microorganisms for fermenting plant materials to produce biofuels, for example, might work more efficiently if they gained the genetic ability to prepare themselves for the next step in the process.

Source: Weizmann Institute of Science (news : web)