Bacteria: Understanding Stress Responses

Bacteria, just like all living things, must sense and respond to changes in the environment to survive. Bacteria are exposed to constant, sudden, and harsh fluctuations in their conditions. To adapt to these changes, they have developed refined stress responses, by controlling the processes by which protein complexes are modeled, in order to survive changes in their environment. These stress responses are sometimes very specific for a particular kind of stress.

In this chapter will we study a few of the environmental changes that cause bacteria stress as well as the responses bacteria has to those changes. When bacteria senses a change in their environment or a threat, their signaling systems respond by activating an alternative sigma factor or by activating response regulators. The four main types of responses are:

* Heat/Cold Shock Response
* Oxygen Deprivation Stress Response
* Starvation Stress Response
* General Stress Response

**Heat/Cold Shock Response**

Bacteria encounter temperature fluctuations in their environments and must adapt to these shifts to survive. These fluctuations in temperature can be in the form of seasonal changes, environmental temperature, or rising global temperatures. Temperature is one of the most widespread challenges facing bacteria survival because it directly regulates both structural and functional cell components of bacteria.

When there is a sudden increase in temperature (heat shock), bacteria respond by extracting a specific set of genes (comprised of proteins) under the central control of an alternative sigma factor (sigma 32), which acts as a regulator. The exposure of bacteria cells to higher temperatures invokes a set of heat-shock proteins quickly to help with any damage to proteins. The increased temperature temporarily alters the metabolism of bacteria. The heat shock response in bacteria elevates the production of more than 20 proteins. These elevated proteins act to overcome changes that could have been destructive to other proteins in the bacterium. Once the stress is removed, the heat shock ensures that the bacterium is capable of normal functions. The heat shock response has a quick onset and is short term. This response is a coping mechanism and an emergency type reaction to a change in temperature that the organism believes to be threatening. This is not a long-term solution, but rather a quick response that allows the bacteria to deal with the threat and then quickly return to its normal function. Protein activity does not last indefinitely, which allows the heat shock response to be turned off as quickly as it was turned on. A well-known example of this adaptation is the heat shock response of *Escherichia coli.*

Upon a sudden decrease in temperature (cold shock), bacteria expresses a stress response comprised in a set of proteins, which are induced to counteract the harmful effects of the rapid decrease in temperature. The above protein set is different in that the set released under heat shock undergoes a 5- hour lag phase where bacteria do not grow (during cold shock environment). During this lag phase, the set of proteins comprised for cold shock stress response are transcriptionally upregulated. These proteins are thought to help in the survival and growth of bacteria at sudden decreased temperatures. There does not appear to be a cold-specific sigma factor identified for cold shock, as there is for heat shock.

**Oxygen Deprivation Stress Response**

As single-celled organisms, bacteria rarely live by themselves. Instead, they form biofilms, which are communities in films on surfaces. Biofilms usually produce chemicals that keep them together so that they form a community of large numbers, which protect them from the outside environment. It’s kind of a “get together” for bacteria! However, as the biofilm party gets out of control, an overcrowding issue occurs where each cell has to compete for the limited oxygen present, in order to survive.

Bacteria have different master plans for responding to the overcrowding community and limited oxygen condition. One plan to cope with the low-oxygen condition is to change the structure of the biofilm or community so that the cells inside are able to access the oxygen on the outside. Another option is to make molecules called phenazines, which are like ubers or taxis! They transport electrons from the inside to the outside of the cell so all the members of the biofilm get a good share of oxygen and thus have the opportunity to survive.

**Starvation Stress Response (SSR)**

Starvation of an essential nutrient is a stressful situation for bacteria. The changes that a bacterium goes through, both genetic and physiologic, in response to starvation stress is known as starvation stress response. It is not uncommon for bacteria to be found in nutrient-limiting conditions. Bacteria have developed starvation-survival techniques that allow them to survive prolonged periods of starvation until conditions improve and they are able to receive the nutrients needed to grow again.

Cryptic growth is thought to play an important role in starvation survival. This is defined as the recycling of nutrients (derived from dead cells) for maintenance of a few surviving cells.

Another response to starvation is the formation of endospores. Endospores can survive extreme environmental conditions that would normally kill most bacteria. Endospores can survive conditions such as high temperature, high UV irradiation, chemical damage, and enzymatic destruction (1). This process (the formation of endospores) may happen when bacteria discovers that the nutrients they are accustomed to surviving on are exhausted, so the bacteria begin looking for other forms of nutrients. This method of survival is initiated when starvation occurs. The formation of endospores allows the bacteria to produce a dormant and highly resistant cell to preserve the cell’s genetic material in times of extreme stress. (1)

**Envelope Stress Response**

The *Escherichia coli* cell envelope is a protective barrier at the frontline of interaction with the environment. (2) The envelope must remain intact and repaired when damaged by environmental conditions. Envelope stress responses (ESRs) sense damage to the envelope and make necessary alterations to the transcriptome to stop the stress. The stress-sensing ESRs provide quick regulators when cells face stress. The Cpx envelope stress response is involved in the maintenance and protection of the *Escherichia coli* cell envelope when stressors such as elevated pH develop.

The bacterial cell envelope is the first line of defense when it comes to threats against the environment. The bacterial cell envelope gives the cell it’s shape and helps resist high internal osmotic pressure. One of the most important things about the bacterial cell envelope is that it is the target for most antibiotics. Monitoring and maintenance, along with repairing of any damage from the environment is crucial for survival.

**Review**

Bacteria have outstanding survival mechanisms. They produce proteins in response to both heat and cold shock in order to protect the cell. Bacteria are also able to form communities called biofilms that keep bacteria together and protect them from the environment. During times of adversity, bacteria has the capability of changing their characteristics so that they can survive and grow. Bacteria can enter into a dormant state and exist for years as a tough spore. Bacteria are also able to produce many generations quickly.

Perfect growth conditions are rarely found for bacteria in their natural environments. They are accustomed to being exposed to stressful conditions. Bacteria have an arsenal of stress responses in their back pocket ready for just about any stress-induced situation. In many cases a single stress response can repair any damage done while eliminating the cause of the stress. However, life in the world of bacteria survival is brutal, with strong competition for which bacteria will survive, due to lack of nutrition, oxygen, and space. The responses bacteria have to the environments around which they try to survive are important; understanding stress response is crucial to the development of modern medicine and bacteria combatant substances.

**References**

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