EC MICROBIOLOGY
Review Article

Bacteria can (Eat, Move, See, Smell and Talk) the Five Senses of Human but in Different Way

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Abstract

It is undoubtedly that the senses of living organisms has a lot of importance in communications and protection and differs according to its evolution bacteria as prokaryote has primitive life was not expected to possess the senses as human, but scientists have found that it has four out of five of these senses will be demonstrated in this review article is not to their importance only primitive as the recent discoveries about the bacteria, but due to its importance in controlling and treating the pathogenic bacterial diseases.

Keywords: *Bacterial Senses; Bacteria See; Bacteria Talk; Quorum Signaling*

Introduction

According to Dennett, sensor can be described purposely: it is a "micro-agent, a finally minimal designed system whose life project is to ask only one question, over and over - 'Is my message coming in NOW? And spring into limited but suitable behavior whenever the answer is YES" [1].

Bacteria can sense according to John S. Parkinson, a professor of biology at the University of Utah, "bacteria as most organisms in life can sense light, gravity, sound, pressure, and chemicals" [2]. A lot of processes just like (changes in temperature, osmolarity, pH, noxious chemicals, DNA-damaging agents, mineral abundance, energy sources, electron acceptors, metabolites, chemical signals from other bacteria, and parasites) can be sensed and respond to it by *E. coli* bacteria [3]. The sensitivity to chemicals of bacteria are very high - for example, E. coli bacteria has five various types of sensors to detect the food. As Muller, Lengeler and Di Primio [4] demonstrate the swimming of common bacteria like *E. coli* towards attractants when it were in chemical gradients (e.g. glucose) or go away from repellents (e.g. benzoate) – this is called a chemotaxis phenomenon. In addition to what was known as phototaxis and magnetotaxis, or response by movement to light and magnetic fields, respectively [5]. Bacteria have chemosensory signaling pathway, which contain the phosphorylation (combination with phosphorus compounds) of some proteins which present in the bacterial cell cytoplasm [6]. Bona fide senses are the name which should be used for the sensitive capacities of bacteria.

The existence of senses practically was teleological cause as mentioned by Aristotle: they are characteristic abilities, which help animals to live. Without these abilities, animals cannot secure themselves from danger or get their requirements. This is the fact of animal's life: "mostly everybody that travels to do its nature's function attains its goal of life without destruction must have perception" [7].

Bacteria are sensitive to light, chemicals, magnetic fields etc. due to what is called its data-encoding devices or specialized "receptors". These receptors may be activated or not, according to the local environment. A bacterium move by two ways the first one which called: run movement (it is occur when a bacterium's flagella, rotate in a counter-clockwise direction) and the second one called: random tumbling (which occurs when a bacterium's flagella rotate clockwise due to alteration in its direction suddenly). When the target was recognized by the external section of a bacterial receptor and bound, sequential changes have been caused by signal passes through the rest of the receptor and in two proteins within the bacterium. (This two-protein sensing system is present in all bacteria and in many other forms of life, except animals). Kinase is the first protein is which found next to the receptor which normally, activates the regulator (a second protein) the regulator that is consequently react with the gear shift of a bacterium's flagella, leading to turn clockwise in case of absence of signal which occurs once every second leading to random tumble of bacterium. This activation of regulator protein by kinase cannot be done in case of signal presence leading to flagella continuous turning counterclockwise makes the bacterium swims in straight movement towards the target without tumbling [8]. Also the bacterium receptors have a type of memory it is for short time where it can store data about their objects for short time. On Aristotle's account, there is no reason for denying this bacterium short memory about a lot of their objects just like (attractants and repellents), in addition to (i.e. concentrations of attractants) [9]. All of the previous characteristics of bacterium have been described briefly by the word about the bacterium as "little animals" or "animalcules" which have been mentioned by van Leeuwenhoek, for the first observation of bacteria under microscope [10].

Mostly and actively and due to their small size bacteria probe their surrounding environment much more than other organisms since they are too small to gauge spatial variations in the concentrations of molecules in their environment. All cellular organisms have sensors which store the data about their surroundings. Excluding viruses which not included in prokaryotes and eukaryotes to be described as "cellular organisms". So this review aims to clarify these senses and its importance in recent researches.

Bacteria can eat even plastic

Bacteria are a unicellular organism and contain thousands of species. The bacteria metabolic category generally determines its diet. According to that they are classified into three categories: lithotrophs, organotrophs or phototrophs. Inorganic material consumed by what is called lithotrophic bacteria; however organic compounds consumed by organotrophic bacteria to obtain their energy. Respiration is the process of in which bacteria food catabolism occurs to obtain their energy. The other bacteria which obtain their energy from the sun called phototrophic bacteria. Some bacteria consume decaying matter and help in recycling waste. Others consume their surrounding chemicals environment as a food. Some is considering even harmful products such as arsenic, oil and nuclear waste as a food consuming it. Bacteria use channels in the walls of membranes and cells to absorb nutrients through instead of chewing or swallowing in a mouth the food like the other living organisms. Bacteria can feed lonely or together in different forms of groups as cluster, chains, squares or various pairs [11].

Plastic products extensively worldwide are made from Poly (ethylene terephthalate) (PET) and has become of a global concern its accumulation in the environment. Due to the thought that the biodegradation of PET enzymatically has a limitation to a few fungal species, it does not yet become one of is the viable priority of recycling strategy. A novel bacterium, *Ideonella sakaiensis* 201-F6 was isolated, can consume PET as major source for its energy and carbon this results have been demonstrated by screening natural microbial communities exposed to PET in the environment. This consumption occur by two enzymes produced by the previously mentioned bacteria which react to hydrolyze the PET to terephthalic acid and ethylene glycol which both considered an environmentally benign monomers, Which make this bacterium plays an important role in degradation of plastic [12].

Bacteria can move

Many prokaryotes response to a chemical or physical stimulus by directionally motion. Generally, there is a thought that bacteria are too small for direct sensing of a concentration gradient through the cell: but they probe alterations in stimulus concentration over time, as reviewed by [13] in the classic paradigm of flagella-mediated chemotaxis in *Escherichia coli*. When moving across a spatial gradient concentration of an attractant, *E. coli* cells alters the experience temporal concentration due to its sense obtained by employing a biochemical memory that lead to a "biased random walk". Swimming directly in a straight manner (run) instead of (tumble) motion. Also Tumbles become run motion when cells sense a temporal increase in attractant concentration [14].

Phototrophic prokaryotes alter their movement in response to the light environment because light is the main source of energy, depending on intensity and wavelength. (reviewed in [15] the first noted of bacterial phototaxis was in 1883 [16] and has been determined in free-swimming phototrophs including *Halobacterium* spp and purple bacteria [17]. *Cyanobacteria*, move by what is known as gliding on moist surface not by flagella. [18]. Directed towards a light source, thus known as true phototaxis [19].

Cyanobacterium *Synechocystis* sp. PCC 6803is the model unicellular (hereafter Synechocystis) it described as spherical cells about 3 μm in diameter using Type IV pili (T4P) in its movements [20]. This movement is generated by pilus retraction of this pilli depending on the location of the T4P extension motor PilB1 implies that pili are extended at the leading edge of the cell [21], as it has been demonstrated in other bacteria [22]. Recently it has been established that cyanobacterium is also T4P-dependent, so this form of motility may be is widespread in cyanobacteria [23]. Except the marine *Synechococcus* spp., which swims as chemotaxis without any obvious surface appendages [24] however there is short spicules found in one of the motile *Synechococcus* strains [25].

There is a one way for bacterial response to environmental change this is occur by motion. The switching occurs due to the transmission of sensory signals which respectively change the concentration of small phosphorylated response regulators that attached to the rotary flagellar motor lead to switching. Generally, a paradigm for sensory systems has been obtained by this simple pathway. However, it seems to be that all bacterial species have the same central sensory mechanism but the increasing number of sequenced bacterial genomes shows somewhat addition of complexity in a wide range of species [13].

Bacteria can see

Since the recognition for the first time of bacterial phototaxis have been occurred over a century ago but how it is done meaning how the bacterium can sense the direction of illumination has remained unknown. The motion of the unicellular cyanobacterium *Synechocystis* sp. PCC 6803 by Type IV pili and which has a range of photoreceptors measures light intensity and color [26]. The phototaxis of *Synechocystis* T4P-dependent can be microscopically observed at the unicellular level and through the migration of cell colonies macroscopically. The phototactic behavior under various light systems occurs mainly due to a number of photoreceptors that have been identified by genetic studies [27]. The *Synechocystis* lacks the CheR methyltransferase and the CheB methylesterase that are important in most chemotactic bacteria to sense temporal changes in attractant concentration while it harbors signal transduction systems for pilus biogenesis that are homologous to the chemotaxis system in *E. coli* [28]. This is control the various mode of direction.

A lot of previous studies have not addressed the question of how the *Synechocystis* single cell phototaxis might be able to perceive the direction of illumination [29]. However Nijland and Burgess demonstrated that the unicellular *Synechocystis* cells can directly and accurately determine the position of a unidirectional light source, and control their motility so as to move towards it. Which give the conclusion that the *Synechocystis* cells act as microlenses, and as a result of this lensing the light intensity gradient across the cell effect is high greater than the effects of shading as a result of light absorption or reflection. Finally, to make specific excitation of one side of the cell using highly-localized laser excitation result in movement away from the light, explaining that positive phototaxis results from movement away from an image of the light source concentrate on the opposite side of the cell. Essentially, determine that the cell play role as a microscopic eyeball [26].

Bacteria can smell

However it was thought that “olfaction” only done by eukaryotes as it is known to be a more complex form of life. Bacteria - among the simplest life forms on Earth - have a sense of smell that a bacterium commonly present in soil can sniff and react to ammonia in the air as demonstrated by Scientists from Newcastle University in the UK. Which has implications in the understanding and control of biofilms - the bacteria chemical coat that can form on, especially, medical implants. Dr Nijland, University Medical Centre Utrecht said that “If bacteria have ability of this since it is very simple organisms that means this ability already present much earlier than expected and this is well known because of the presence of bacterial senses to detect chemicals which lead to presence of other bacteria or competitors for food. In some cases, they can stick together in what is known as a biofilm by producing a slimy material. This biofilms lead to a lot of complications such as teeth plaque. Dr Nijland and Grant Burgess put in cylinders containing different "growth media" a number of separate cultures of a bacterium called *B. licheniformis* to multiply. Bacteria which grow in enriched broth media reproduce rapidly leading to formation of ammonia gas which consequently lead to formation of biofilms due to contact with ammonia gas. At the same time some of the isolated bacteria cultures when it is in contact with the well fed bacteria began to show the highest production of biofilms and this is occur spontaneously, which can be explained as that the biofilm act as a barrier and transportation means for the bacteria that have "smelled" nearby ammonia. The bacteria which have this sense and can ordering themselves to form a biofilm use this way as protection and competition with other species already feeding on the nutrient source, and also to migrate through this layer of matrix which secreted to produce biofilm. The well understanding this phenomenon will help us to prevent biofilm related bacterial infection by developing methods interfere with this process [26].

Bacteria can talk

Bacteria are unicellular microorganism according to the classical point of view of prokaryotic life, response only to external physical or chemical environmental stimulus. Now it is well known in bacteriology that bacteria also communicate with each other by organic compound small like hormone called autoinducers (Als). These signal communications called quorum sensing as it is initially described as mechanisms responsible to regulate gene expression through cell density. The Als interact with regulatory proteins when they reach a threshold concentration, by driving bacterial gene expression. Bacterial intercellular communication leads to coordinated population behavior by providing a mechanism for the regulation of gene expression. Quorum sensing control a various functions and requires a particular species of bacteria live in a given niche. Quorum sensing-controlled have include conjugation among others, bioluminescence, biofilm development and virulence factor expression. Enteric pathogens control the virulence genes just like type III secretion and motility using quorum sensing. Also the normal intestinal flora uses the quorum sensing to sense the presence of and to success in colonization of the host [30].

The maximum benefits of bacterial cell activities which controlled by genes just occur when done by groups of bacteria acting in synchronization and it is mainly by quorum sensing [31].

Quorum sensing systems mainly depend on three basic principles even if there are differences in regulatory constituents and molecular mechanisms, all known QS systems depend on three basic principles. The community members produce AIs that is signaling molecules, firstly. If the concentrations are low below the threshold cannot be detected due to low cell density (LCD), AIs diffuse away. However at a local high concentration there is high cell density (HCD), lead to a cumulative production of AIs which stimuli detection and response [32]. Secondly, the receptors which present in the cytoplasm or in the cell membrane detect the AIs. Thirdly, activation of AI production which result in autoinduction loop presumably promotes synchrony in the population at the same time lead to activate genes expression which important for cooperative behaviors. The QS systems used by Gram-positive bacteria differ from that used by Gram-negative bacteria. As peptides signaling molecules use d by Gram-positive bacteria, called autoinducing peptides (AIPs) [33]. The communication in Gram-negative bacteria occurs via small molecules as AIs. Which are either acyl-homoserine lactones (AHLs) or other molecules depends on S-adenosylmethionine (SAM) as a substrate in its production [34].

Mainly the production of pathogenic bacteria virulence factors regulated by QS. For example, QS in *Vibrio cholerae*, a Gram-negative bacterium control virulence factor production and biofilm formation by using two parallel two-component. Even *P. aeruginosa* and *S. aureus* cause persistent diseases while *V. cholerae* and *B. cereus* cause acute infections using QS circuits to promote the specific infection [35].

Conclusion

Comparing someone to bacteria is not far from the truth even it is not nice but as the scientists recently discovered they have four of our five senses.

Two rival species of soil bacterium, *Bacillus subtilis* and *Bacillus licheniformis*, were both found to react the same way to amm¬onia emitted by the other. They created differing amounts of biofilm in direct proportion to how far away the rival bacteria were.

From an evolutionary point of view, the simple bacteria may be the first example of how living creatures firstly learned to smell other living creatures.

Recently, scientists discover that the bacteria can 'see' by reacting to light, 'feel' by responding to physical touch, 'taste' by direct contact with environmental chemicals and 'smell' by detecting airborne molecules. The only sense missing is hearing. The next step is to discover the nose or sensor that does the 'smelling'.

Bacteria can form a slimy biofilm that helps colonise an area and push out competitors and act as the major virulence factor of many pathogenic bacteria as what is known as quorum sensing.

Finally, understanding all these senses can lead to novel antibacterial as these anti-quorum sensing molecules that are being developed as new kinds of therapeutics. So bacteria can do things that we want them to do better than they would be on their own.

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