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Geometric basis of action potential of skeletal muscle cells

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Abstract

Although we know something about single cell neuromuscular junction, It is still mysterious how multiple skeletal muscle cells coordinate to complete the intricate spatial curve movement. Here I propose a hypothesis that skeletal muscle cell populations with action potentials are alligned according to a curved manifolds on space(a curved shape on space) and the skeletal muscle also moves according to this corresponding shape(manifolds) when an specific motor nerve impulses are transmitted. the action potential of motor nerve fibers has the characteristics of time curve manifold and this time manifold curve of motor nerve fibers come from visual cortex in which a spatial geometric manifolds are formed within the synaptic connection of neurons. This spatial geometric manifolds of the synaptic connection of neurons orginate from spatial geometric manifolds in outside nature that are transmitted to brain through the cone cells and ganglion cells of the retina.Further,the essence of life is that life is an object that can move autonomously and the essence of life's autonomous movement is the movement of proteins. theoretically, due to the infinite diversity of geometric manifold shapes in nature, the arrangement and combination of 20 amino acids should have infinite diversity, and the geometric manifold formed by protein three-dimensional spatial structure should also have infinite diversity.

Key words: action potential ,skeletal muscle cells, synaptic connection of neurons ,space curved manifolds, time curved manifolds

Introduction

Before elaborating on today's topic, I would like to raise a question in the field of life science, what is the essence of life, that is, what is the fundamental difference between living things and non living things? There are many answers here. For example, the essence of life is the genetic code DNA[1], or protein, or the cell that can carry out material exchange (metabolism), or the negative entropy that can be studied by physical and chemical methods[2]. All these characteristics of life do not exist in non biological bodies. All of the above are true, but there are many answers. In any case, there is only one answer to this question. In my opinion, the essence of life is that life is an object that can move autonomously. In any case, all the contents of this paper are hypotheses, which have not been confirmed by experiments, but it can give us some positive hints.

So what is autonomous movement? For example, The motion state of an inanimate body (non-organism), such as a basic particle, depends on its interaction with other substances, so its motion is random, that is, quantized motion, so its motion is not autonomous motion. Here I give the definition of autonomous motion, which is independent of other substances and can actively and consistently do any space curve shape motion. We can not find a non-organism that can move autonomously in nature currently. Cell is the object that can do autonomous movement, so the essence of life is cell. The autonomous movement of cells can also be divided into simple and

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complex movements, so organisms have experienced the evolution from single cell to multi cell. Single cell does simple autonomic movement, multi cell does complex and fine autonomic movement. So how does the cells complete its autonomous movement? This is the main contents of this paper.

Results

1 Why do cells move autonomously while other objects can't?

The evolution of nature from inorganic matter to organic matter has experienced a complex process. The origin of cells is the main sign of this evolution. Let's take the single-cell organism as an example to explain why the cell is the basic working unit of autonomous movement. For example, bacteria, although it is a single celled organism, its complex structure is completely used to maintain its own autonomous movement.

The cell membrane has the function of selective permeation, and completes the material exchange inside and outside the cell together with the cell wall. There are respiratory enzymes on the membrane, which participate in the energy metabolism of cells. The cytoplasm is the main site of bacterial metabolism. Ribosome is the site of protein synthesis. Golgi matrix is the basis of protein processing, sorting and transportation. Nucleoplasm is composed of genetic material DNA, which controls the life activity of bacteria and is the material basis of its genetic variation. Flagella are filaments attached to the surface of bacteria and are the motor organs of cells.

All the structures of the cell serve for the autonomous movement of the cell. The ion channel of cell membrane is the controller for the cell to exercise autonomous movement. It transmits the external information to the cell through the amount of ion flow, and the cell completes the corresponding movement according to the amount of information flow of amplitude motion.

The flagellum motor contains a proton pump, which can transfer hydrogen ions to drive the rotation of the proton pump, convert chemical energy into mechanical energy, and then transmit torque to the flagellum joint device, and then drive the flagellum filaments to drive bacteria like a propeller[3].Therefore, the autonomous movement of bacterial cells is simple, and its movement state and direction depend on its surrounding ionic environment..

Protein is the material basis of cell work and a substance that exercises autonomic motion.. Why does protein exist as this material basis? I think the reasons are as follows; 1、 Its physical and chemical properties, such as stretch, flexibility and elasticity, enable it to complete a variety of complex and delicate movements. 2、 A protein is a polymer made up of 20 different amino acids. Its amino acid sequence and spatial position are almost endless, which determines that it can complete the movement of infinite geometry and perform various physiological functions of cells.

2 Multicellular autonomous movement

1） Characteristics and functions of multicellular ion structure

The evolution of life from single cell to multi cell is to complete more complex and fine autonomous movement. As mentioned earlier, ion flow is the driver for cells to complete autonomous movement, and the amount of ion flow determines the range of cell movement. Here we take metazoan animals as an example because they have the ion channel structure of sodium

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potassium pump. Further, we take human ion channels as an example because people can do the most complex and fine autonomous movement. Human skeletal muscle movement is dominated by the brain. The structure and function of ion channels that complete the excitation transfer coupling of nerve skeletal muscle have been systematically and completely studied[4]. We take a single cell as an example to illustrate this transfer coupling process.

In the axoplasm of axon terminals of motor nerve fibers, there are a large number of vesicles with a diameter of about 50 nm, and ACh is contained in the vesicles and ACh stored in each vesicle is usually constant[5][6]. When ACh is released by exocytosis in the unit of vesicles, it is called quantum release. When there is a nerve impulse at the nerve endings, under the action of local membrane depolarization caused by action potential, a large number of vesicles approach the axon membrane, and all ACh in the vesicles enter the junction space through the fusion of vesicle membrane and axon membrane[7][8]. It is estimated that about 200 to 300 vesicle contents can be discharged by the arrival of an action potential[9]. When ACh reaches the end plate membrane surface of skeletal muscle cells through the junction gap, it immediately interacts with the channel protein （sodium potassium pump）on the membrane α- subunit binding causes conformational changes of protein molecules, resulting in channel opening, sodium ion influx and potassium ion outflow, resulting in end plate membrane depolarization[10][11]. This junction transmission maintains a one-to-one relationship, that is, every time a nerve impulse reaches the end of the motor fiber, it reliably excites the muscle cells once and produces a contraction.

Skeletal muscle is composed of a large number of muscle fibers arranged in parallel. Each muscle fiber is a muscle cell, and there are thousands of myofibrils in each muscle cell. Myofibrils take sarcomere as the unit, and the finer structure of sarcomere is myofilament. Myofilament is composed of thick myofilament (main component myosin)[12] and fine myofilament (main component actin)[13][14]. The action potential generated by the depolarization of the end plate membrane of muscle cells leads to the increase of calcium ion concentration in muscle plasma. Troponin binds a sufficient number of calcium ions to cause the conformational change of troponin molecule, which is transmitted to myosin. The conformation of the latter also changes, and its structure has a certain torsion, which leads to the binding of actin and transverse bridge, and the two bind, twist and dissociate, Then combine, twist and dissociate to trigger the cross bridge cycle[15][16]. This cycle causes the fine muscle filaments to slide between the thick muscle filaments to complete the muscle contraction. The transverse bridge has the function of ATPase, which can decompose ATP and provide energy.

2） Mechanism of multicellular autonomic movement

(1) Now a basic question is coming. How can skeletal muscle complete complex and fine autonomous motion, that is, curve or straight line motion with arbitrary shape on space? This is still a mystery. As mentioned earlier, action potential is the driver of cell movement. For a single cell, we have clearly understood the process of completing autonomous movement through ion exchange. So how do the action potentials of multiple cells work to coordinate and complete various forms of autonomous movement? Theoretically, when the nerve impulse in the cerebral cortex is transmitted, each cell is given different motion amplitude and direction through different action potentials. Therefore, thousands of cells with different motion amplitude and direction complete a fine movement of skeletal muscle, that is, a specific curve shape movement. Such action potentials should have the following characteristics: 1. They are not all or none, but

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increase with the increase of stimulation[17]. 2 The resulting cell movement has different directions. 3 can not do long-distance transmission on the cell membrane.

The complexity of such a working mechanism is unimaginable. The subtlety of nature is to describe complex things with simplicity. In fact, experimental studies have confirmed that skeletal muscle action potentials also follow the principle of simplicity. Skeletal muscle action potential has the characteristics of all or none,that is, the action potential of each cell does not change with the stimulation intensity and conduction distance. Therefore, when nerve impulses are transmitted, each cell can only have two possible states, either produce action potentials or do not produce action potentials. So how do multicells perform complex movements according to these two states? Here I propose a hypothesis that cell population with action potentials are alligned according to a curved manifolds on space(a curved shape on space) and the skeletal muscle also moves according to this corresponding shape(manifolds) when an specific nerve impulses are transmitted. Other cells outside this manifolds are in a state without action potential. As shown in **Figure** 1.Different nerve impulses produce different curve manifolds, that is, the switching states of action potentials of different cell groups. Here, all skeletal muscle cells can complete various complex and fine movements as long as each cell of all execute these two on-or-off switching states . It is not difficult to see that the direction of motion of a single cell has been determined by this manifolds. We can also call this manifold of multicellular action potentials as the spatial geometric distribution or spatial summation distribution of action potentials.

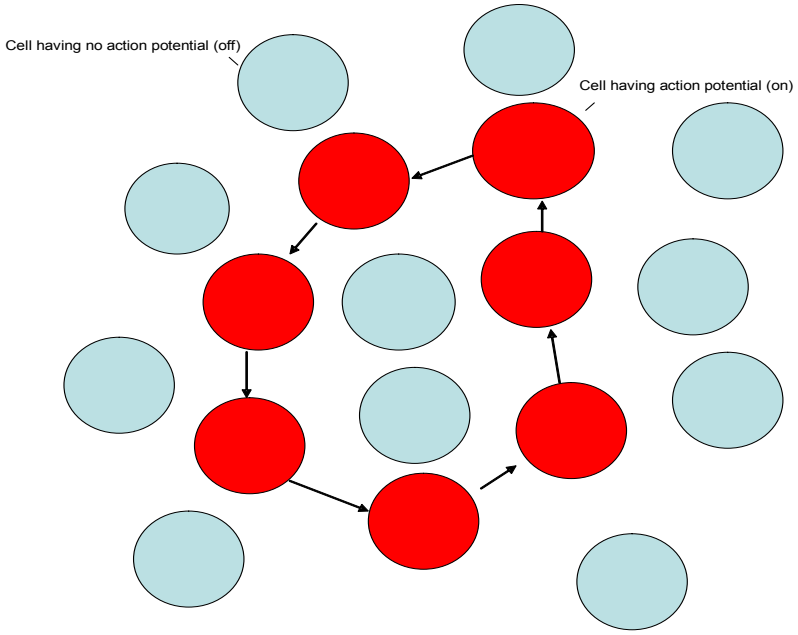

Figure 1 The cell populations with action potentials are alligned according to a curved manifolds on space(a curved shape on space) and the skeletal muscle also moves according to this corresponding shape(manifolds) when an specific nerve impulses are transmitted. Other cells outside this manifolds are in a state without action potential. The cells in red are cells that have an action potential and forms a special geometric manifold . The cells in blue are cells that have no action potential and not manifolds formed.

(2) So the next question comes. Although the excitation transmission between the nerve endings

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of motor nerve fibers and muscle cells is 1-to-1, the relationship between the trunk of motor nerve fibers and muscle cells is not 1-to-1. How do the nerve impulses in the cerebral cortex pass through the trunk of nerve fibers? Here , a concept of temporal geometric distribution (time curved manifolds) is proposed in view of the previous concept of spatial geometric distribution. In other words, the action potential of motor nerve fibers has the characteristics of time curve manifold, so how to understand this time manifold? Because the action potential propagation speed of nerve fibers is constant, the size of this time manifold is defined by the number of excited muscle cells per unit time.As shown in **Figure** 2. this time manifold curve of motor nerve fibers corresponds to space manifold curve of action potentials of skeletal muscle cells.

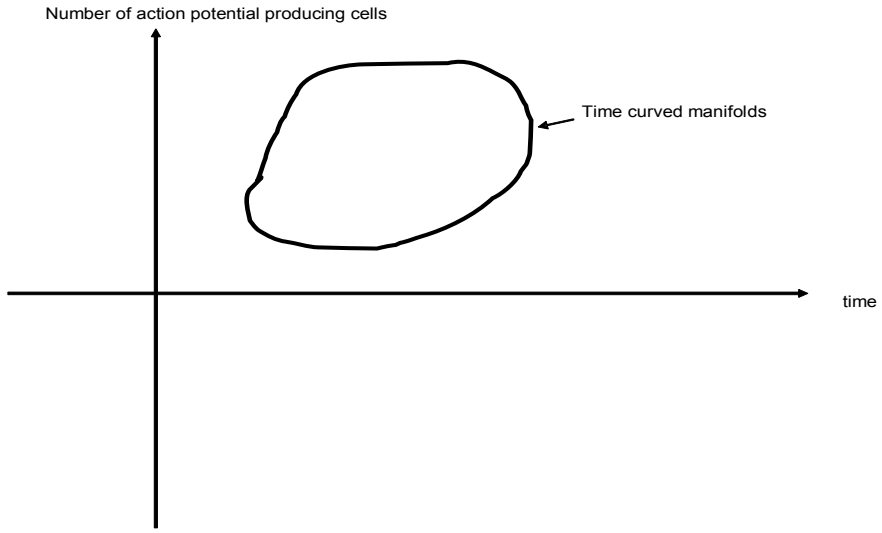

Figure 2:X-axis is time, Y-axis is the number of cells generating action potential, time manifold curve is a function of independent variable x with respect to dependent variable y, and this time manifold curve corresponds to space manifold curve.

(3) Theoretically, the movement of skeletal muscle moves according to the manifold shape formed by the action potential of the skeletal muscle cell group triggered by nerve impulses of motor nerve fibers . This manifold is formed by the spatial distribution of cells with action potential (on), while the other cells do not produce action potential (off). Each manifold is specific, and the actual movement of skeletal muscle also corresponds to this specific manifold. However, in fact, if the skeletal muscle cell group is closely connected in space, and if this manifold is formed by a group of cell groups in space, the movement of skeletal muscle can not be realized.

The same is true. Skeletal muscle consists of a large number of bundles of muscle fibers, which are arranged in parallel. Each muscle cell is a muscle fiber, and each muscle fiber is slender and cylindrical. This structural feature determines that the movement of skeletal muscle only has two linear movements: contraction (shortening) and elongation, but can not complete the complex and fine manifold movement. In order to complete this manifold movement, multiple groups of skeletal muscle cell groups are required to participate. With the cooperation of bone and joint,

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these cell groups coordinate to complete this manifold movement.

Here I propose a hypothesis. Each group of cells can only complete a simple linear motion of shortening and lengthening. The amplitude of this linear movement of each group of cells is determined by the number of cells stimulated to produce action potential. The more the number of cells, the greater the degree of contraction and relaxation (lengthening and shortening) of muscle cells.

In order to complete the three-dimensional manifold motion, three groups of cell groups are needed. One group of cells controls the up and down movement, the second group controls the left and right movement, and the third group controls the front and rear movement. Because each group of cell groups can only move in a straight line, the three groups of cell groups need the participation of bone and joints to complete the three-dimensional manifold movement. For example, in the three-dimensional movement of fingertip cell groups, in addition to their own group of cells controlling the up and down movement, the other two groups of cells controlling the left, right and front and rear directions need the participation of joints. Their contraction and relaxation take the joints as the fulcrum to pull and control the cell groups of the up and down groups to make them do left, right and front and back movement. When different degrees of motor nerve fiber impulses come, the different number of cells excited to produce action potential in each of the three groups of cell groups determines the degree of fingertip up and down, front and back, left and right movement, resulting in various complex geometric manifold movements.Of course, this motion of space manifold curve of action potentials of skeletal muscle cells also corresponds to the time manifold curve of motor nerve fibers.

（4）As mentioned earlier，the three-dimensional manifold movement of skeletal muscle moves according to the manifold shape formed by the action potential of the skeletal muscle cell group triggered by nerve impulses of motor nerve fibers, ans motor nerve fibers carry this geometric manifold information in the form of time manifold, Motor nerve fibers carry this geometric manifold information in the form of time manifold, so there is no doubt that this manifold information comes from the motor center cortex of the brain, so how does the motor cortex transmit this information? Here I propose a hypothesis. As mentioned earlier The essence of life is autonomous motion, and the essence of autonomous motion is geometric manifold motion. Therefore, geometric manifold is the most basic determinant of all life. Therefore, the manifold information of cerebral cortex comes from nature that acts on our sensory system.

The external geometric manifold information is transmitted to the visual cortex through photons

When an external object with geometric shape is projected to the eye through the optical system, the photon binds to the photoreceptor (rhodopsin) [18] on the membrane of the outermost photoreceptor cell (mainly cone cell) of the retina. The conformation of the latter changes, activates the opening of the chemically gated Na channel of the cell membrane, and generates a hyperpolarized receptor potential. This receptor potential spreads to its axon terminals with electrical tension, affects the release of transmitters here, and triggers the formation of action potential in its lower ganglion cells.This potential has the cumulative characteristics of quantity, and does not have the characteristics of all or no action potential. In fact, cones and bipolar cells do not have the ability to generate action potentials, but only ganglion cells can do. There are about 6 million cone cells and 1.2 million ganglion cells in the human retina[19]. Each ganglion cell is connected with 40000-60000 cone cells through dendrites. Ganglion cells form optic nerve fibers through long axons and project to the visual cortex.

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When objects with different geometry manifolds project photons to the visual system, the number of photons absorbed by cones is different, and the number of ganglion cells producing action potential is also different.

Just as the motor nerve fibers mentioned above have the characteristics of time manifold, the cone cells and ganglion cells also have the characteristics of time manifold when transmitting external space manifold information where spatial geometric distribution in outside nature corresponds to temporal geometric distribution (time curved manifolds) of the cone cells and ganglion cells . The time manifold of cone cells is calculated by the number of photons bound by visual receptors per unit time, and the time manifold of ganglion cells is calculated by the number of cells producing action units per unit time. Thus, the geometric manifold of an external space can be described by the time manifold of cone cells and ganglion cells. Of course, this time manifold can be projected by ganglion cells to the visual cortex through the optic nerve.

（5）So how does the time manifold information of ganglion cell action potential transfer to the visual central cortex? Unlike the action potential geometric manifold of skeletal muscle cells, which has wide spatial ductility, the neurons in the visual certex are closely connected. The limitation of the skull makes it impossible for these neurons to have motion space. Therefore, the time manifold of ganglion cells will be stored in the visual cortex in another way. Here, I propose a hypothesis that the synaptic connection of neurons of visual cortex will form a spatial geometric manifold, which corresponds to the temporal geometric manifold of ganglion action potential.

When ganglion cells (optic nerve fibers) transmit nerve impulses to the visual cortex through the lateral geniculate body that has multiple synaptic connections with the visual cortex, the geometric manifold of synaptic connections between neurons in the visual cortex will be formed. Due to the different manifold shapes in the external space, the geometric manifold shapes of synaptic connections between neurons are also different correspondingly, and the two have a one-to-one relationship. So how does this geometric manifold of synaptic connections form?

When the impulse of an optic nerve fiber with a special time geometric manifold is transmitted, the action potential generated by the visual cortex neurons also has a time sequence. When the first neuron generating the action potential conducts excitation to the neurons adjacent to it, its conduction direction is also specific, which is transmitted according to the direction specified by this special geometric manifold, That is, it is only transmitted to the adjacent cells in the direction consistent with the manifold shape, not to the adjacent cells in other directions. When this transmission is continuous, a synaptic connection between neurons with a special geometric manifold is formed.Seeing **figure** 3.

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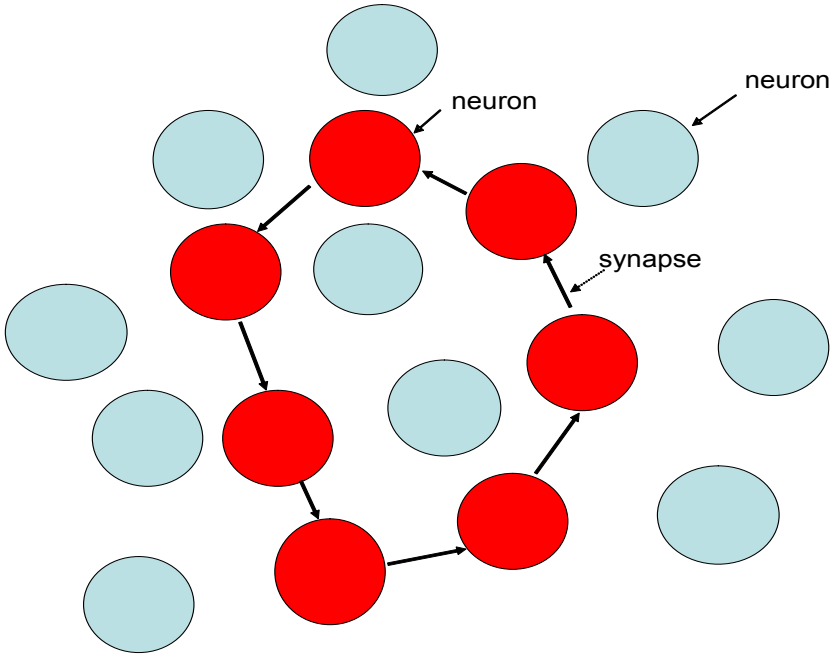

Figure 3 When the first neuron generating the action potential conducts excitation to the neurons adjacent to it, its conduction direction is also specific, which is transmitted according to the direction specified by this special geometric manifold, That is, it is only transmitted to the adjacent cells in the direction consistent with the manifold shape, not to the adjacent cells in other directions. When this transmission is continuous, a synaptic connection between neurons with a special geometric manifold is formed .The neurons in red are neurons that have an action potential and form synapses in a particular direction. The neurons in blue are neurons that have no action potential and do not form synapses in a particular direction.

When a new special geometric manifold from the outside is transmitted through the impulse of optic nerve fibers, there is no existing synaptic connection with this shape between neurons, so it is necessary to form a new synaptic connection with this special shape. It is known that the synaptic connection between neurons is mainly axon-cell body connection, which is composed of presynaptic membrane, synaptic space and postsynaptic membrane. The action potential transmission of this synapse is unidirectional and mediated by neurotransmitters.

Synaptic structure is mainly composed of proteins, so the formation of a new synaptic geometric manifold loop requires the synthesis of new proteins, which is a complex process. Studies have shown that the formation of an axon-somatic synapse is mainly mediated by the axon guidance pathway.This axonal guidance mechanisms are mediated by many molecules,such as netrin(midline axonal guidance),Neuroglian and Fasciclins(longitudinal axonal guidance)[20],and so on.

The formation of a new synaptic geometric manifold loop can not be generated by only one impulse transmission, and it can only be generated by many times of the same stimulation. Therefore, it also shows that the synaptic geometric manifold does not have infinity, that is, which manifold shape is generated and consolidated between neuronal synapses completely depends on the stimulation intensity and duration of this shape that are emerged in the visual pathway. On the contrary, if a new synaptic manifold can not be consolidated and strengthened for a long time,

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then this manifold may be gradually lost, which is called memory loss.

Long term memory and short-term memory can be explained by this concept[21]. A long-term memory is the generation of a synaptic manifold, which represents the synthesis of new proteins. A short-term memory means that there is no synthesis of new proteins. It is just a new external manifold stimulation, which is similar or consistent with the existing brain synaptic manifold. On the contrary, how a new synaptic manifold can not be consolidated and strengthened for a long time, then this manifold may be gradually lost, which is called memory loss.

From here we can see that the synaptic manifold of neurons is the basis and essence of memory. The more synaptic manifolds, the stronger the memory and the stronger the ability of logical thinking.

In natural evolution, the cortical cortex of the brain has a division of labor, so the cerebral cortex of higher animals is divided into many areas[22], such as the motor center controlling skeletal muscle movement and the visual center cortex controlling vision. How do they relate,or how does the movement center cortex start the geometric manifold movement of skeletal muscle? It is speculated that they have an intermediate nerve nucleus connection similar to nerve fibers or have multiple synaptic connections with each other. This needs further research, As mentioned earlier ,how the action potential manifold conducted by visual nerve fibers leads to the new synthesis of neuronal proteins and synapse formation is still a mystery now.

3 Protein is the basis of autonomous movement of life

As mentioned earlier, The essence of life's autonomous movement is the movement of proteins. There are only 20 basic amino acids that make up proteins, but their arrangement and combination has the possibility of infinite diversity, which is also conform to the law of nature to express complex diversity with simplicity. The geometric manifold movement of skeletal muscle is mainly performed by myosin and actin on muscle fibers with the participation of other proteins. With the aid of bone and joint, only a limited number of proteins can complete various complex manifold movements(but can't move on an infinite number of manifold shapes). However, theoretically, due to the infinite diversity of geometric manifold shapes in nature, the arrangement and combination of 20 amino acids should have infinite diversity, and the geometric manifold formed by protein three-dimensional spatial structure should also have infinite diversity. The transformation from one manifold to another (change of autonomic movement state of life) only needs to change the arrangement and combination of amino acids.

Because DNA is genetic material and protein synthesis takes it as a template, the infinite diversity of arrangement and combination of 20 amino acids also determines the infinite diversity of arrangement and combination of 4 nucleotides(infinite diversity of genes), which also follows the natural law of expressing complexity with simplicity.

Theoretically, if a large number of proteins and genes are placed in a cell or arranged in a system, from gene to protein ,and the movement of proteins from one shape to another, will become extremely complex in this organism. Living organisms take cells as the working unit to solve this problem. There are fewer proteins and genes in each cell, and the division of labor of each cell is the same or different/ Instead of the direct change of a group of three-dimensional manifolds composed of many proteins, in the connection between cells, the change of manifolds can be realized only by increasing and decreasing the number of cells. Therefore, the physiological

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replication and apoptosis of cells are essentially to meet the needs of protein manifold change. Manifold change in cells has the following advantages. 1 Each cell has fewer genomes and produces fewer proteins, and its time and process are simplified. 2 for manifold changes containing more proteins, only the replication and apoptosis of their cells can be changed without direct change.Here, the protein-protein interaction (a small group of proteins connected with a small group) replaces the overall connection of a large group of proteins.

From these reasons, it can be seen that the essence of life is autonomous movement, and the material basis of autonomous movement is protein. Therefore, autonomous movement is the change of protein geometric manifold. Further, protein geometric manifold is the essence and basis of all life phenomena. Gene expression, gene regulation (gene protein interaction) and protein synthesis regulation are all aimed at changing this geometric manifold.

Under the stimulation of various external pressures, when skeletal muscle or other organs need to move in a new geometric manifold that does not exist in the synaptic connection of their own nerve center, the three-dimensional manifold structure of protein needs to meet and merge into this manifold shape, so the genes mutations that controll protein synthesis occurs.It has been suggested that transposon can change genome size and cause mutations, Here it may occur for the purpose of changing the geometric manifold of proteins. When mutation or other reasons lead to the dissociation of protein-protein interaction, multiple cells die, resulting in a large area of protein fracture (collapse of geometric manifold), and the organism begins to senescence or death.

4 Perspectives

In future, To confirm the properties of the spatial geometric manifolds of the synaptic connection of neurons of visual cortex , the probes are needed where the individual spikes can be distinguish reliably in temporal resolution and action potentials of large scale neuronal populations of local field of visual cortex can be measured[23]. Furthermore, when hundreds and thousands well-isolated single neurons are simultaneously recorded from different fields of visual cortex in awake animals, A surprising experimental results may be presented.

structures in an awake mouse

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Declarations

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