

Molecular Biology Research on the Information Coding Mechanism of Brain Nerve Cells

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Abstract. The function of the brain is to integrate information and make behavioral decisions accordingly. The understanding of brain function is an important part of neuroscience, and it also provides inspiration for artificial intelligence. However, how information is represented and encoded in the brain, and how it is read by other downstream tissue links, these questions have not yet been clarified. To explore the regulation of information expression by molecular biology during the in vitro development of human fetal brain neurons. These cytokines all promote the expression of neural cells at the transcriptional level, laying the foundation for analyzing the molecular mechanism of their biological effects.

Keywords: Molecular biology; brain; nerve cells; information coding.

1. Introduction

In the process of brain development, the proliferation period of nerve cells determines the total number of neurons that will constitute the brain in the future and controls the rate of neuron generation. The developing cerebral cortex is composed of two types of neural stem cells that are epidermal growth factor and basic fibroblast growth factor-dependent. The two types of neural stem cells differ in their generation time, spatial distribution, and differentiation potential to different neural cells. In the embryonic brain of organisms, basic fibroblast growth factor-dependent stem cells are first produced in embryonic stage 8.5d, and epidermal growth factor-dependent stem cells evolve from basic fibroblast growth factor-dependent cells at about 14 days [1]. It mainly in morphological enlargement and antigenic production of epidermal growth factor receptor. Both types of embryonic stem cells can generate neurons and glial cells under suitable induction conditions, but the basic fibroblast growth factor-dependent stem cells mainly differentiate into neurons, while the epidermal growth factor-dependent stem cells mainly produce neurons [2]. Dopamine D1 receptors have been shown to affect cell proliferation in multiple systems including lymphocytes, meningeal cells, and vascular smooth muscle cells [3].

The main function of the brain is to integrate various sensory signals, and to make and implement behavioral decisions based on the received information. The study of brain function is not only one of the main tasks of neuroscience, but also provides inspiration for the development of artificial intelligence. Neurons are the basic structural and functional units of the brain's nervous system. They fire action potentials driven by excitatory inputs, and transmit signals to downstream neurons or effectors through the release of neurotransmitters to encode and transmit neural information. While it has been demonstrated that neuronal information processing in the brain involves the activity of neurons, some key questions remain to be answered [4]. The excitability of neurons is often measured by the frequency of action potential firing, but the firing frequency itself is a measure based on statistics, while the processing of neural signals is a process of integrating and transmitting immediate signals. It has thus been recognized that while the frequency of action potential firing reflects neuronal excitability, neural information is carried by the time-series structure of action potential firing. However, in the neuron network of the brain, a neuron often accepts signal input from multiple previous neurons, and a single neuron can also provide output for multiple downstream neurons. More importantly, how can we effectively extract the neural information carried by the neuron population through the measurement and analysis of the activity[5].see Fig. 1.

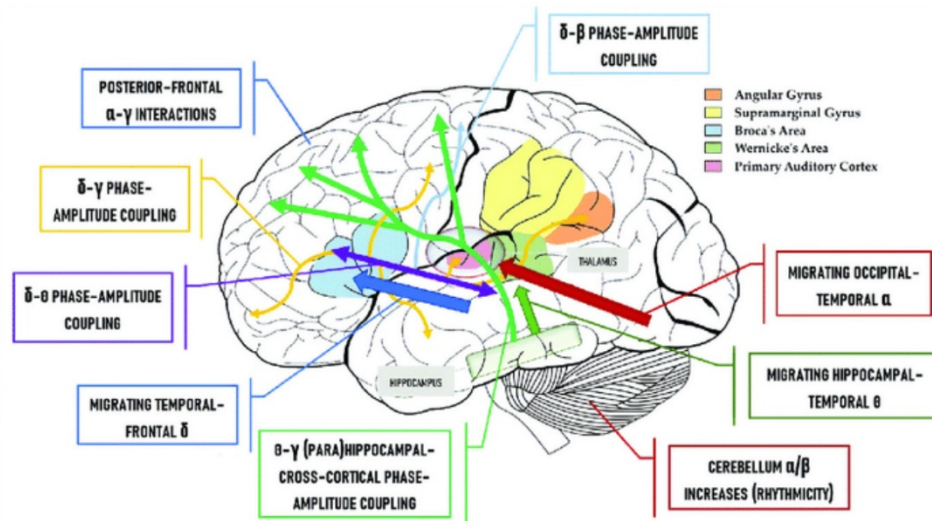


Fig. 1 Brain neural coding model structure diagram

In recent years, academic researchers have analyzed motor neuron activity obtained from human or other animal brains and extracted their characteristics to drive robotic arms and implement motor intentions. These works have seminal implications for how brain intentions can be read by recording brain activity. However, the human brain has many other functions, including the perception, comparison and calculation of sensory information, as well as more advanced functions including learning and memory, emotion and expression, thinking and reasoning. The realization of these functions is also inseparable from the activity of neurons, but relevant information, especially the information carried by intrinsic processes, is a basic problem in neuroscience and cannot be avoided in the realization of high-performance brain-computer interfaces.

2. Classical neural coding model of the brain

The cerebral neurosensing system of the human brain is mainly composed of the peripheral brain, primary cerebral neurocortex, extrastriate cortex, and advanced cerebral neurocortex. The primary cerebral neurocortex (area V1) receives the information flow from the transit station, the lateral geniculate body, performs the first step of processing in the cerebral neurocortex, and transmits the processed information flow to the higher neuronal regions. The information flow is transmitted to the extrastriate cortex, and the first region to pass through is mainly to receive the information flow processed by V1, and also partially connect with the lateral geniculate body.

Nerve cells in the primary cerebral cortex and extrastriate cortex mainly process some simple brain neural features, such as orientation, location, color, and texture and shape, while the features processed by optic nerve cells in the advanced visual cortex are significantly more complex. In recent years, the construction of classical brain neural coding models for different brain neural regions has been widely studied.

2.1 Feeling model

Simple cells in the V1 region exhibit direction, location, and spatial frequency selectivity to brain neural stimulation. The researchers used wavelets of different phases, locations and spatial frequencies to simulate the receptive fields of simple cells, and established a pyramid-structured receptive model from brain neural stimulation to brain response, so as to predict the response of the visual cortex to natural images. Based on the perception model, image reconstruction is realized by combining Bayesian method and image semantic prior. The time information is added to the traditional perception model to construct a spatiotemporal receptive field. The sensory model was applied to the coding of the primary cerebral cortex when the subjects performed the image imagining task, and it was found that the model could effectively predict the brain response and identify the

imaginary pictures when performing image imagining. Biologists proposed a class feature to improve the accuracy of the mapping between low-level features and brain activity. After this process established the mapping, the weighted linear least squares method was used to obtain the inverse mapping, which made the image recognition of the two subjects in the experiment accurate. The rate increased from 90% and 78% to 94% and 95%, respectively. In addition, the model can also realize image reconstruction without prior, and the system has certain reversibility.

2.2 Classical coding model of advanced brain regions

For high-level brain neural areas, based on the information encoding model of brain nerve cells, the video stimuli are first labeled with different category labels, and then the finite impulse response regression model is used to obtain the label weights. The predicted voxel response is obtained by multiplying the two. The researchers combined the prior semantic information and used the latent Dirichlet allocation algorithm to make scene predictions for natural images.

A coding model for the higher-level cerebral neurocortex during experiments. Biologists study the ventral temporal cortex involved in text reading and face recognition tasks. The model first extracts feature by a set of filters, and then normalizes the dot product of the output to calculate how well a given stimulus matches a class template. Brain neurons encode information and faces exhibit selective responses. The model has fewer parameters and is more computable and interpretable, and it is also the first model to explain the selective response of the brain to high-level brain neural features.

In general, the features extracted by the classical coding model fit the neural mechanism of the human brain and have good interpretability, but the features are based on manual design. Although the computability is good, the feature expression is limited, and the prediction accuracy is not high enough. Most models cannot achieve reversible decoding. see Fig. 2.

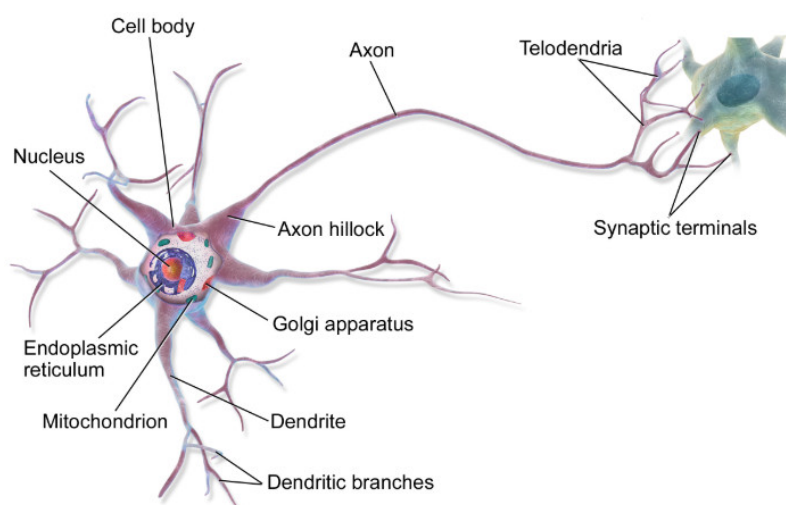


Fig. 2 Morphological plasticity and functional conduction of brain neurons

3. Neuronal morphological plasticity

The research team recently discovered the function of the protein kinase GRK5, which is widely present in the body, in the nervous system, as well as the new mechanism of regulating neuron morphology and plasticity, which will contribute to diseases such as autism and Down syndrome caused by abnormal neuron development. provide new ideas for treatment and drug development. The discovery was recently published in the internationally renowned academic journal "Journal of Cell Biology". Neurons, also known as nerve cells, are the basic units that constitute the structure and function of the nervous system. Tens of millions of neurons in the brain are the basis and basic unit of brain functions such as emotion, memory and consciousness. The formation and remodeling of brain neural networks depend on neuronal morphogenesis and dynamic changes. Both neuronal cytoskeletal remodeling and cytoskeletal membrane deformation play important roles in neuronal

morphogenesis and dynamics, but how neurons coordinate cytoskeletal membrane deformation and cytoskeleton remodeling to promote neurite outgrowth. The connection between neurons and neurons has always been a mystery. Young researchers in Malan's group have obtained an unexpected answer through biochemical, cellular and animal experiments: GRK5 can act as a bridge in the nervous system in another way, that is, one end of GRK5 can bind to the cytoskeleton in the brain, causing cells Skeletal remodeling, the other end of which can guide the remodeled cytoskeleton to the PIP2-enriched cytoplasmic membrane region by binding to the specific phospholipid "PIP2" on the neuron cell membrane in the brain, thereby coordinating cytoskeletal remodeling and cell membrane deformation, promoting the morphological changes of neurons and the formation of connections between neurons. Many diseases affecting cognition, such as autism, mental retardation, fragile syndrome, Down syndrome, etc., are accompanied by abnormal neuronal morphological development. Their study found that GRK5 has a new function of promoting neuronal morphological development, proving that GRK5 is an important protein that promotes the formation of neural networks, regulates brain learning and memory and other functions. New targets are provided.

4. Research on brain neural information encoding based on synchronous oscillation

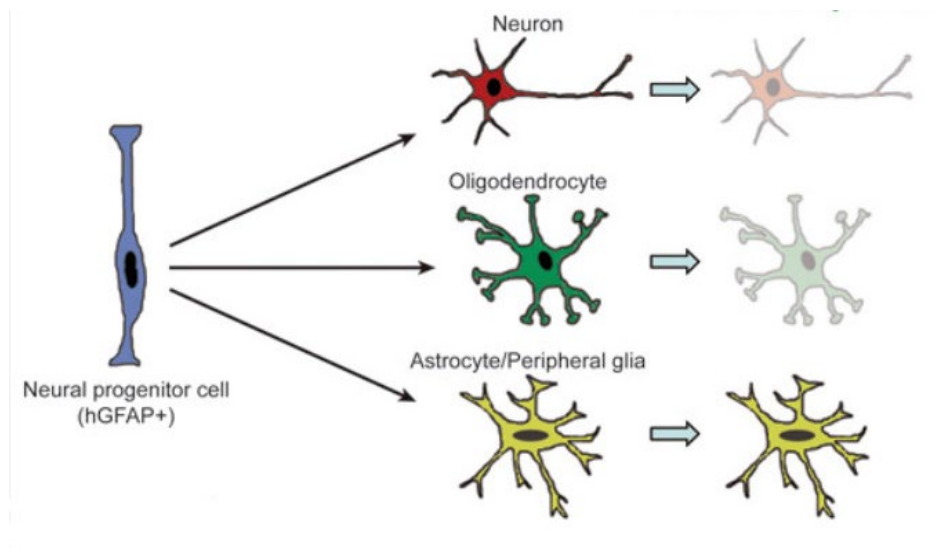


Fig. 3 Flow chart of neural stem cell proliferation

On the basis of the electrophysiological network model, combined with the actual proportion of the number of various neurons in the olfactory bulb and taking into account the computing resources, a network model with somatic cells, parabolbar cells and granule cells was constructed. Although the ratio of paraglobular cells/somatic cells and granulosa cells in the model is lower than the actual ratio in physiology, it has been ensured that there are far more paraglobular cells and granulosa cells than somatic cells, and the ratio of paraspheric cells to granulosa cells is in line with the physiological ratio. In the model, the range of paraglobular cell array and granule cell array that form synaptic connection with each somatic cell is $R_p=0.5$, $R_g=0.5$, and the random probability of connection is 0.8. Due to the mutual inhibitory effect between the parasphere cells, the parasphere-parasphere junction was introduced in the model, and because the parasphere cells are short synaptic cells, here it is set to form a mutual inhibitory sphere with each parasphere cell. The array radius of the paracells was 0.12 nm. The primary dendrites of the somatic cells and the cells adjacent to the ball are stimulated by external currents. During the calculation, the relative amplitude of the current input to each cell is used to simulate the input of a kind of information. The stimulation current input to the somatic cells is evenly distributed between $[0.5 \text{ Between } \sim 1] \times 1.7\text{nA}$, the stimulation current input to the cells adjacent to the ball is evenly distributed between $[0 \sim 1] \times 30\text{pA}$, and a noise with an amplitude of 1~10% of the maximum stimulation amplitude is added to the stimulation, through the simulation

calculation of this model (simulation time is 1000ms) to study the encoding of different stimulus information by olfactory bulb neurons. In the network model, the output voltage responses of any two somatic cells and any two parasphere cells show the raster diagram of the soma and the local field potential when the soma and parasphere cells and granule cells do not have any synaptic connections. The amplitude of stimulation input to each somatic cell is different, so it exhibits asynchronous firing, however, when a range of synaptic connections is introduced between paraglobular cells and somatic cells, and between granulos cells and somatic cells, somatic cells show After a certain synchronization, the firing frequency of somatic cells is around tens of hertz.see Fig. 3.

5. Neural stem cell proliferation research

5.1 Culture of isolated neural precursor cells

Appropriate for epidermal growth factor-supported neural stem cell proliferation studies by dopamine D1 receptors Antigen subtype analysis of isolated neural precursor cell cultures revealed that these cells embody the cellular composition of the proliferative zone of the embryonic brain. The cultured cells contained not only undifferentiated pluripotent stem cells, but also immature glial cells and neuronal cell precursors, which was similar to previous reports on the composition of neurospheres. A large number of epidermal growth factor-supported neural stem cells are still proliferating, and different phenotypes become more differentiated during the culture process, among which phenotype neural precursor cells tend to increase, while neuronal precursor cells decreased, and these results are also validated by previous studies. At the same time, immunofluorescence staining also showed that the vast majority of these precursor cells contained dopamine receptors. These characteristics all reflect that the culture of isolated neural precursor cells supported by epidermal growth factor is suitable as a research model to study the mechanism of dopamine receptors on the proliferation of neural stem cells in the brain.

5.2 Dopamine D1 receptor inhibits epidermal growth factor

Probe into the Proliferation Mechanism of Supporting Neural Progenitor Cells In this experiment, it was fully confirmed that the activation of dopamine D1 receptors can inhibit the proliferation of neural progenitor cells located in the proliferative area of the embryonic brain. First, it was found that dopamine D1 receptor agonists can inhibit the uptake of BrdU by epidermal growth factor to support neural precursor cells, thus showing the decrease of DNA synthesis ability in cell proliferation, and this effect is concentration-dependent. In order to further clarify the mechanism of action of the drug, flow cytometry was used to determine the effect of the drug on the number of cells distributed in different cell cycle phases. The results confirmed that the D1 dopamine receptor agonist SKF38393 mainly increased the number of cells in phase 1 and decreased the number of cells in phase S, thereby increasing the proportion of cells distributed. Apoptosis test showed that the drug only made a large number of cells stagnate in the G0-1 phase, but was not accompanied by an increase in the level of apoptosis, which indicated that the activation of dopamine receptors had no cytotoxic effect within the concentration range observed in the experiment. , which is only a temporary pause in the proliferation of precursor cells. Moreover, after the removal of dopamine receptor drugs, the stagnant cells could restore the original proliferation level, and the effect of SKF38393 did not change the distribution ratio of each antigen subtype in the epidermal growth factor-supporting neural precursor cells. These results indicate that the dopamine D1 receptor only induces the stagnation of the proliferation of neural precursor cells, and does not cause the increase of apoptosis, nor the differentiation of cells out of the proliferation cycle to terminal neurons.

6. Conclusion and Discussion

In this paper, the method of establishing an animal electrophysiological network model is introduced in detail, and on this basis, the temporal synchronization encoding of different brain

stimulation information is studied. First of all, the following conclusions can be drawn from summarizing the full text: (1) The firing frequency and firing waveform of brain cells obtained by analyzing and comparing simulation calculations are basically consistent with the actual electrophysiological experiments of brain nerve cells; (2) According to the actual brain nerve cells Physiological experiments have shown that molecules can cause the release of synchronous oscillatory spikes in brain nerve cells, and the interaction of cells is the reason for the formation of local field potentials. In the olfactory glomerulus module, the merging and integration of receptor input information (spatially encoded information) is achieved through synchronization between neurons, and the synchronized responses of different neuron groups at different times form the response to objective stimuli (different Molecular combination) time coding, which is basically consistent with the current research conclusions.

From the research of the model, there are three aspects that need to be further studied. First, quantitative analysis methods such as synchronization index can be introduced to explore the different roles played by MC, GC and PG neurons in brain neural information encoding from a comprehensive, holistic and systematic perspective. An important reason and feature. Secondly, it will focus on establishing an information encoding pattern recognition method based on instantaneous synchronous spatiotemporal encoding, that is, if a molecular biological information can be expressed as several basic linear combinations, what are the concentrations of these basic molecules and their ratios? In the brain, it is achieved by means of instantaneous synchronization of spatiotemporal coding. By adjusting the network topology and introducing the algorithm of spatial distance, the role of different cells on the neural recognition of the brain is studied.

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