MANUAL

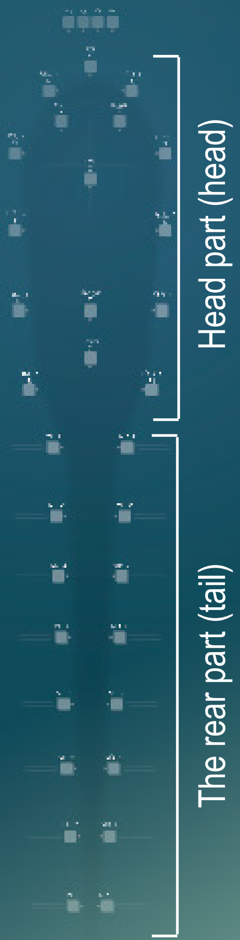
OPENTadpole

THE FIRST CYBERNETIC ANIMAL

2017

Brief information

There are two modes in the OPENTadpole system: ConnectomTadpole and SimWorldTadpole
ConnectomTadpole - editor of connectom tadpole
SimWorldTadpole - body simulation of the tadpole and the environment



The editor allows you to edit the nervous system of the tadpole, create neurons and connections between them (synapses), and customize them.

The tadpole has two parts: the head part (head) and the tail part (tail). At the head part there are receptors, which supply incoming signals to the nervous system. Next to each indicator of the receptor is the indicated key of the keyboard, by pressing the corresponding key, the receptor is activated. In addition to receptors skin pressure (11 pcs.), food sensing receptors (2 pcs.), photosensitive receptor (1 pc.), as well as the receptor for starvation (1 pc.) and fatigue (1 pc.), 4 special receptors F1, F2, F3 and F4 for additional effects on the tadpole's nervous system and experiments.

In the tail part there are motor units (16 pcs.), which are indicators of the output signals of the tadpole's nervous system. Next to the motor unit is an intensity indicator that shows the level of impact on the motor unit, taking into account the time factor.

Simulation of the environment allows modeling the external manifestation of the work of the tadpole's nervous system.

The tadpole consists of segments, totaling 9 segments. Segments are connected by a virtual kinematic pair (joint). Each joint is affected by a pair of virtual muscles that can change their length (contraction) and have a certain elasticity.

The mechanical properties of the external environment are modeled by the method of hydrodynamics of smoothed particles (SPH). The visualization of these particles can be turned off with the F12 key.

The simulation of the liquid medium allows the tadpole to float freely within the designated rectangular region. Contact with the boundaries of the aquarium is perceived by pressure receptors on the skin of the tadpole, the tadpole feels food and senses whether the lighting is switched on at its place of stay.

Link to source code github.com/BelkinAndrey/OPENTadpole

Mode switch button

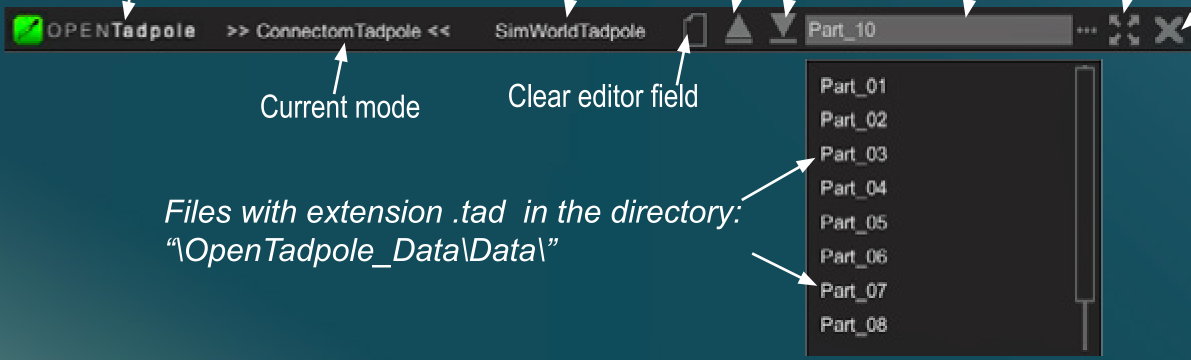
Download

Save

Input string for file name

Full screen mode

Close



Current mode

Clear editor field

Files with extension .tad in the directory: "\OpenTadpole_Data\Data\"

ConnectomTadpole

Select an object

Editor's menu

Moving

Zoomed

SimWorldTadpole

The "finger" tool You can touch the tadpole

The "food" tool

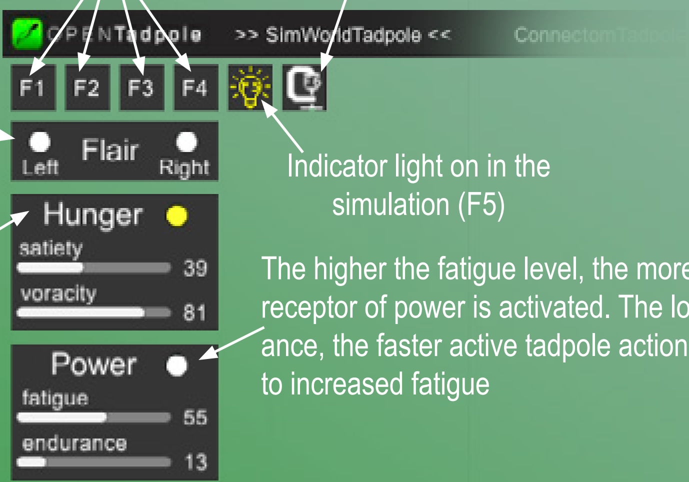
Moving

Zoomed

A "vise" tool is a fixation of the tadpole over the head and a continuous effect on the skin pressure receptors, under certain conditions this causes the tadpole to wriggle in an attempt to escape

Special receptor activation indicators

Two indicators of receptor activity of food sensing, the closer the food, the more often they are activated



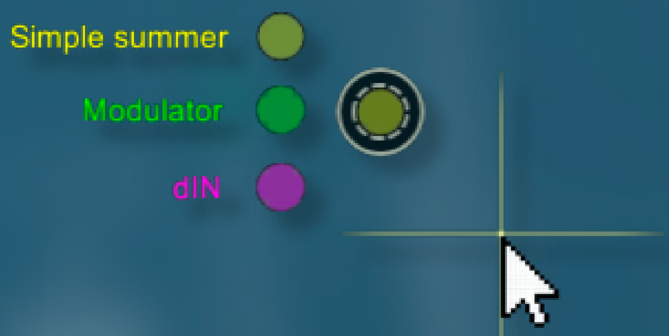
Indicator light on in the simulation (F5)

The lower the satiety level, the more often the hunger receptor is activated. The higher the voracity, the faster the satiety decreases

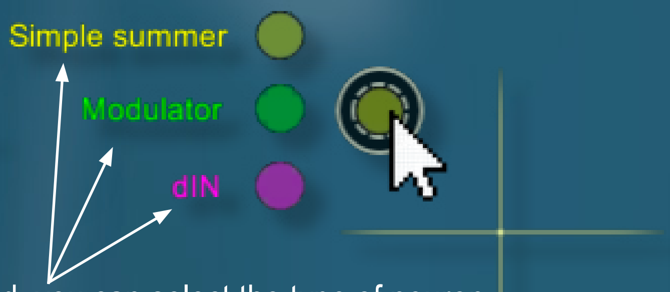
The higher the fatigue level, the more often the receptor of power is activated. The lower endurance, the faster active tadpole actions will lead to increased fatigue

Creating a neuron

1). Press and hold the right mouse button, the editor menu should appear.



2). While holding the mouse button, move the pointer to the corresponding icon and release the button. A new neuron will be created at the cross-hair.



While the mouse button is being pressed, you can select the type of neuron you are creating. There are only three types of neurons: simple summer, modulator and neuron of the tadpole generator (diN). It is enough to point a pointer to the necessary type of neuron to change the type of newly created neuron.

Removal of the neuron

When you click on the left mouse button over the neuron it is possible to select it, and it is also possible to select multiple neurons using the selection frame.

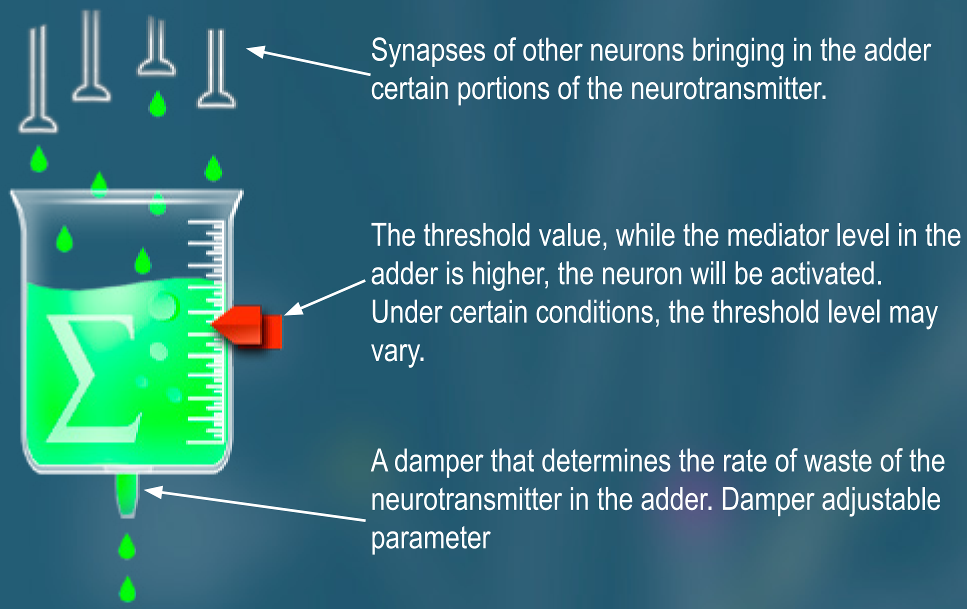
If at least one neuron is selected, then a garbage basket icon appears in the editor's menu. If you release the right mouse button when the pointer is over it, then all the selected neurons are deleted together with all the connections (synapses) that they had.

Creating a synapse

If only one neuron is selected, an icon for creating synapses appears in the editor's menu. Selecting it, the mode of creation of synapses in which it is possible to choose target neurons with which communication will be formed will be switched on. This mode can be disabled by clicking the right mouse button.

Model of the neuron

The summation is the main functional property of the neuron. The model of the neuron summator of the OPENTadpole system can be represented in the shape of a vessel in which a neurotransmitter arriving from the synapses of other neurons accumulates. Each such synapse selects a certain portion of the neurotransmitter upon activation. But the neurotransmitter is continuously wasted in the synaptic cleft, it is destroyed by a special enzyme or absorbed back through the synapse membrane, so our vessel has at the bottom a small hole - a damper through which the total amount of the neurotransmitter is wasted. If the level of the neurotransmitter in the adder exceeds a certain threshold value, then the neuron will be activated, and after each activation the neuron will need time for recharging. Thus, the time factor is taken into account in the adder, with small and rare portions of the neurotransmitter, the neuron may not be activated, and with a strong action, a whole series of activations is possible.



There are two types of direct-acting neurotransmitters: stimulant and inhibitory. The portion of the released neurotransmitter by the synapse upon activation in the system is determined by the real number and can be negative. There may also be a negative amount in the adder. If we continue the analogy of the adder with the vessel, then two types of neurotransmitter will be mutually destroyed, falling into the adder, and the inhibiting neurotransmitter will also be spent over time.

Setting neuron

To open the neuron configuration window, you need to select only one neuron and in the editor menu, the corresponding icon will appear, selecting which will open the neuron settings window.

A simple adder has only the basic functionality of the adder, it is the simplest model of the neuron in the system.

The identification number of the neuron in the system

Neuron type index (0 - Simple adder; 1 - Modulated neuron; 2 - Neuron of tadpole movement generator (diN))

Value of the current amount

The maximum value of the adder

The minimum value of the adder

Threshold value. In parentheses, the current threshold value.
If the amount exceeds this value, then in case the neuron is not active and not the stage of rest, activation will take place.

Damper - the value by which the module of the sum will decrease every millisecond.

The response time, the time in milliseconds after activation, through which the neuron activates its synapses.

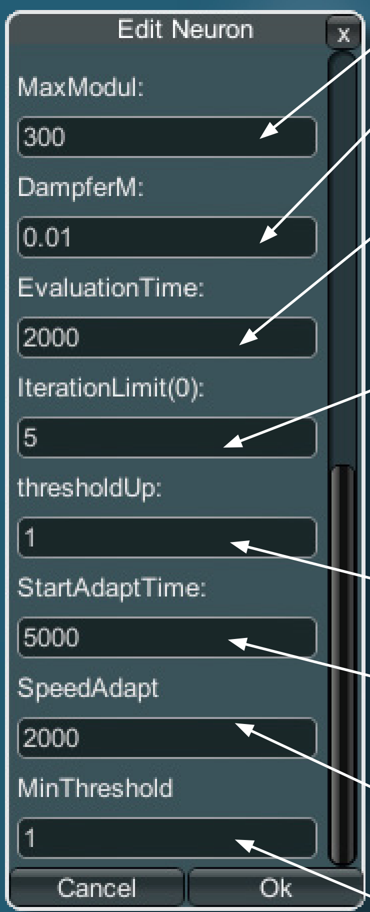
The rest time, the time in milliseconds after activation of the synapses, during which the neuron can not be activated.

The modulated neuron has all the properties of a Simple adder and a number of additional functions. A feature of this neuron is a dynamic change in the threshold value under the influence of modulating synapses or the properties of habituation and adaptation.

Modulation is a property of a neuron, the ability to change its characteristics and parameters under the influence of a certain type of synapses. Due to the effect of modulating synapses in the neurons of the OPENTadpole system, the threshold varies, and like the sum of the adder, the modulation value changes with time, the threshold value returns to the initial state at the speed determined by the damper.

Addictive - the property of the neuron, which determines the mechanism for reducing the level of sensitivity of the neuron when it is activated repeatedly. Frequent activation of a neuron by a synaptic contact of a chemical type leads to a decrease in the probability of activation of a neuron by the same level of action of a given synaptic connection.

Adaptation is a property of the neuron, which determines the mechanism of increasing the level of neuron sensitivity with the course of prolonged inactivity. The probability of the neuron's triggering from a weak effect increases with prolonged derivation (absence of stimuli) of the neuron.



The maximum value of modulation, an increase in the threshold due to the effect on the neuron of the modulating synapse.

The damping factor of the modulating factor, the value by which the threshold will change every millisecond, tending to reach its original value.

Evaluation time, the time in milliseconds counted from the end of the rest period of the neuron, if during this time the neuron is activated, the re-activation counter will increase, after this time the counter is reset.

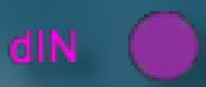
The limit of repetitions, the maximum value of the retry counter after which the threshold begins to increase with each repeated operation. This parameter is associated with the process of habituation, determines some margin of stability of the work of the neuron before the beginning of habituation. In brackets, the actual value of the retry counter.

The value on which the threshold will increase with each re-activation after the limit has been exhausted.

Time of the beginning of adaptation, the time of the absence of activations, after which the adaptation will take place - a gradual decrease in the threshold level.

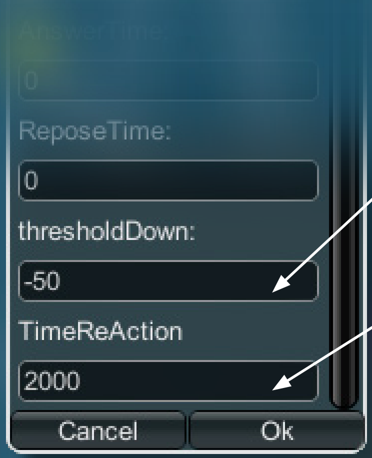
Adaptation speed, time interval, in which the threshold will decrease by 1.

The minimum value of the threshold to which adaptation will occur.



The neuron of the tadpole movement generator, the neuron, whose specific properties were adopted from the biological analogue. It has all the same properties as the Simple adder, but in the case of a situation where the sum on the adder falls below a certain value (the lower threshold), normal activation will occur, but with some delay (reactivation time).

Additional settings:



The lower threshold, the threshold value at which the reactivation mode is activated, activation after a period of inactivity.

The reactivation time, the time in milliseconds defining the period of inactivity, counted from the moment of the sum decrease at the adder, is lower than the lower threshold, this period always ends with activation of the neuron.

Neurons dIN can generate an action potential upon exiting inhibition (post-inhibitory rebound)

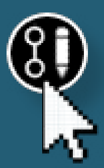
Model of the synapse

There are three types of synapses in the OPENTadpole system:

Synapse of direct action (I) - the synapse effect on the adder, has the characteristic force, is determined by the real number. Strength can be negative, which indicates the inhibitory effect of the synapse.

Synapse of modulating action (M) - a synapse under the influence of which some characteristics of the neuron change, in the OPENTadpole system, under the influence of the modulating synapse, the threshold value changes. The force parameter of this type of synapse determines how much the threshold will change, but the threshold value can not fall below zero and increase above the maximum of the modulating action.

Electrical synapse (E) is a synapse whose activity will lead to activation of the neuron, if possible. Does not have the parameter force.



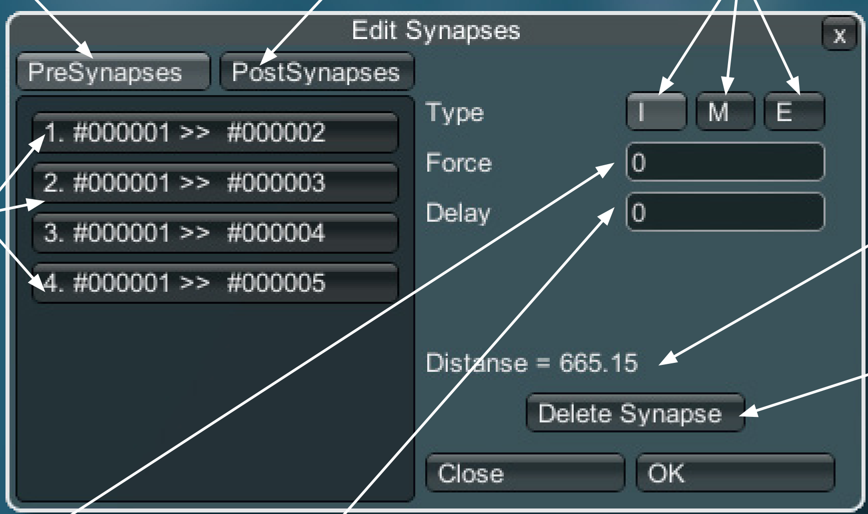
To open the synapse settings window, you need to select only one neuron and in the editor's menu the corresponding icon will appear, selecting which opens the window for setting the synapses.

Display a list of all outgoing synapses

Display a list of all incoming synapses

Buttons for switching the type of synapse:
I - Synapse of direct action;
M - Synapse of modulating action;
E - Electrical synapse.

A list of synapses by clicking on the button from the list will show the corresponding synapse in green in the editor



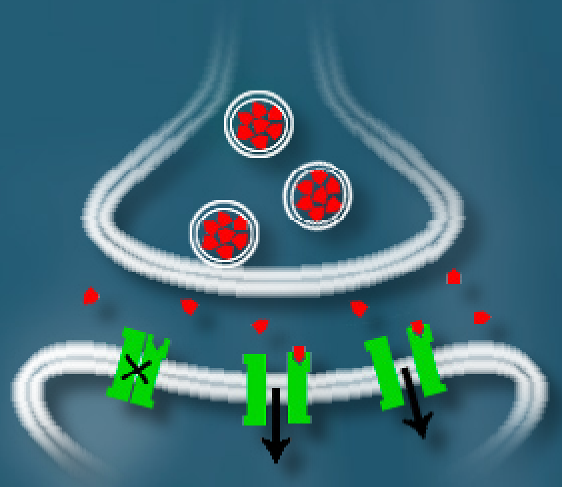
The relative distance between the bound elements is only informative.

Button for removing the synapse.

The strength of the synapse, it may be negative, that in the case of a synapse of direct action indicates the inhibitory effect of the synapse. For the contact synapse is ignored.

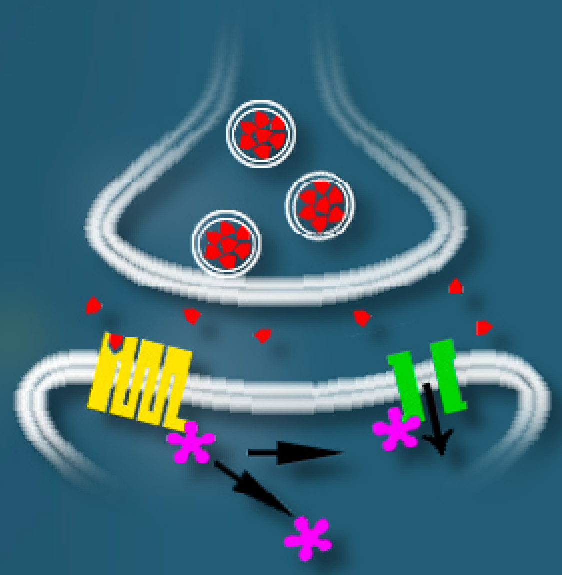
Delay in milliseconds, with which the signal will pass through the synapse. The propagation velocity of the nerve impulse is finite and on average is 1 m/s, depending on the extent of myelination in different axons, this rate may differ. Also, in the transmission of excitation in the synapse, a synaptic delay may occur. This parameter allows simulating various kinds of delays in signal transmission in the system.

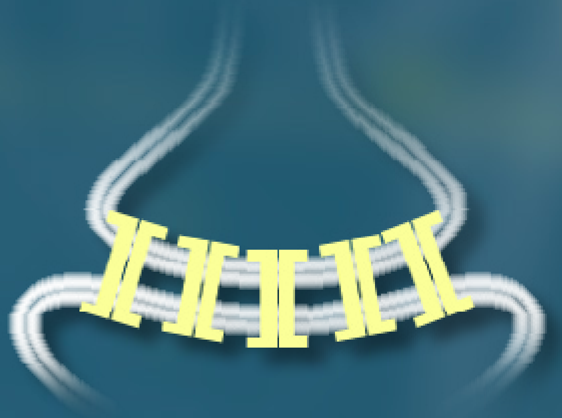
Synapses of the OPENTadpole system have their analogues in the biological nervous system.



Ionotropic receptors are a combination: an ion channel + receptor. The ion channel opens when its receptor interacts with an appropriate neurotransmitter. The more such channels are open, the greater the likelihood of the occurrence of an action potential. Such type of receptors can be compared with synapses of direct action, and stimulating character. The density of receptors on the postsynaptic membrane is analogous to the level of the adder threshold, the more receptors on the membrane, the more sensitive the neuron to the action of the mediator, the lower its activation threshold.

Metabotropic receptors, receptors that, when interacting with a neurotransmitter, release some mediator substance, which in turn can have various changes in the work and metabolism of the neuron. The mediator can open or block the opening of the ion channels, which affects the mechanism of summation in the neuron, and can also have a modulatory effect: reduce or increase the density of ion channels and receptors in the synapses, influence the overall growth of the neuron and its neuroplasticity, affect synaptic delay , Change the level of addiction and other metabolic properties. Metabotropic receptors are the impetus of modulating synapses in the OPENTadpole system.





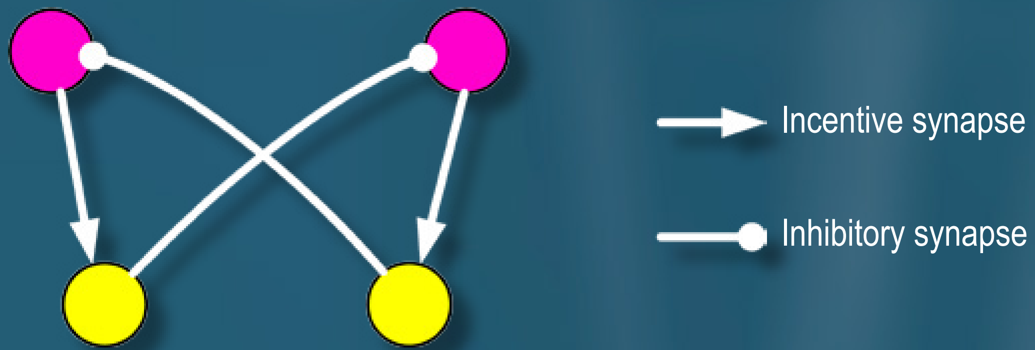
Electrical synapses are synapses in which the transfer of action potential from cell to cell is transmitted directly through special contact channels, without the use of chemical mediators. This type of synapse is not determined by strength and sensitivity only by the presence of a fact of communication.

Motion Initiation

Initially, there are 10 conservation examples in the system that will allow you to learn the nerve patterns that allow the tadpole to swim, maneuver, react to irritants, touch, look for food and avoid obstacles.

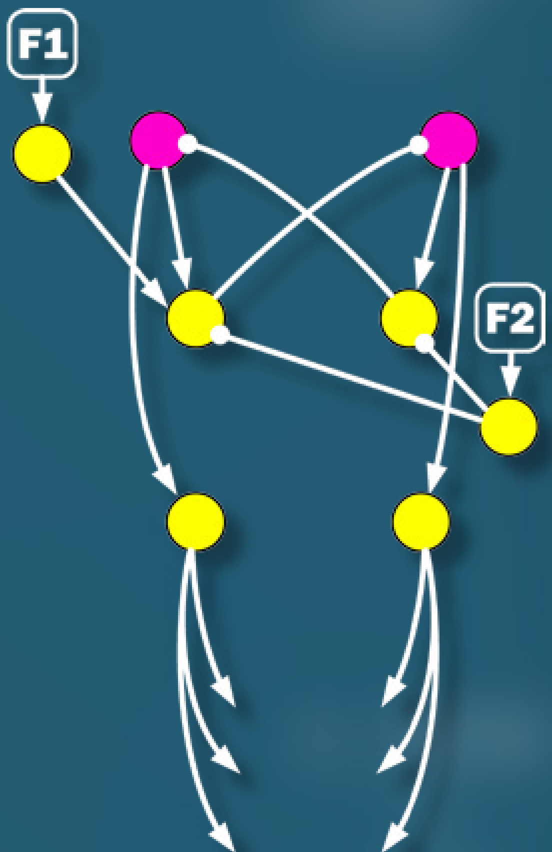
Part_01

Motion Generator:



An ordered activity generator is a source of rhythmic nerve impulses that can be transformed into motor activity. The diagram shows the neuron scheme, which is observed in the tadpole, this structure is repeatedly repeated and is located along the trunk of the tadpole. Conservation uses only one generator, in biological systems, redundant duplication provides reliability and stability of operation.

The tadpole's motion generator consists of two dIN neurons located at the sides, which, through intercalating inhibitory neurons, cross-retard each other. If one neuron is activated dIN, then the other neuron will be inhibited, after a while the excitation in the first neuron dIN will pass, and in the second, activation will occur due to the release from the inhibitory state (post-inhibitory rebound), thus the alternating activity in the opposite parts of the neural circuit.



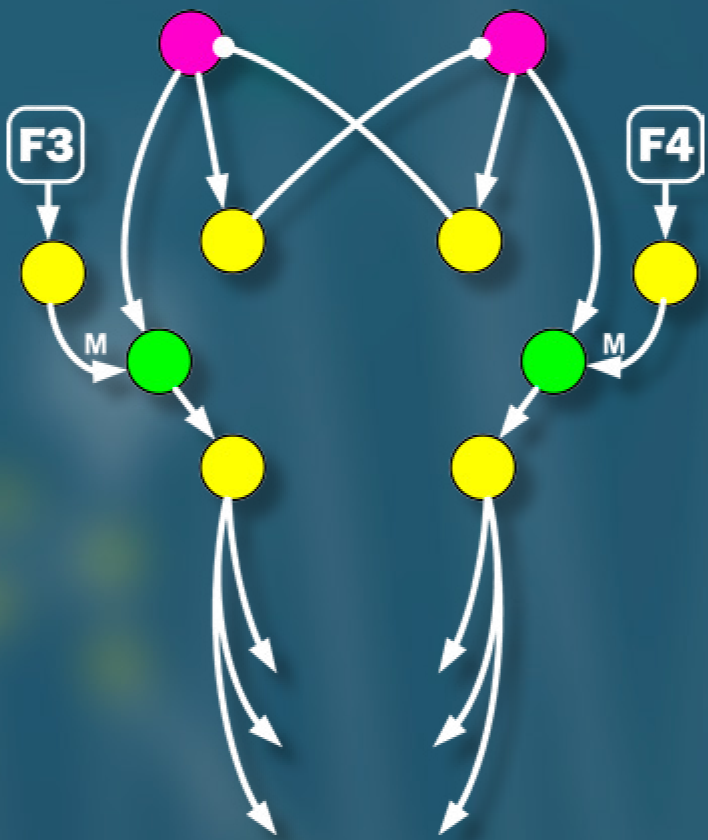
Control elements can be added to the scheme:
- F1 receptor triggers a motion generator;
- F2 receptor suppresses activity in the generator.

From the generator on each side there are signals to the motor neurons along the body of the tadpole. These signals are delayed sequentially from the body of the tadpole to the tip of the tail, in Part_01 the delay interval is set to 100 milliseconds, which creates the effect of the excitation wave propagating along the body.

Start Part_01 in SimWorldTadpole mode, press the F1 key, the tadpole starts to make swimming movements. Press F2, the tadpole stops swimming.

Maneuvers

Part_02



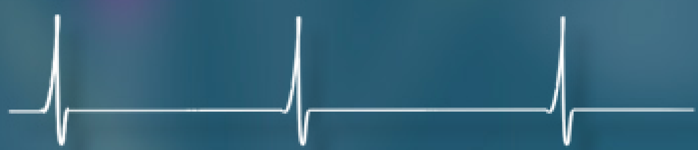
To make a turn when swimming, the muscles of the tadpole should, on the one hand, contract more intensively, and the rhythm of swimming should be preserved at the same time. For more intensive contraction, certain muscles should be sent more frequent signals.

Depending on the level of the threshold, the rate of reduction of the sum on the adder and the level of effect on the neuron, it can be activated by whole series.

By lowering the threshold level in the modulated neurons (green) with the help of modulating synapses (M), it is possible to control the nature of motor neuron activation.

The F3 receptor will cause the tadpole to float to the left, and F4 to the right, with the active motion generator.

Not modulation:



Modulation:

Start Part_02 in SimWorldTadpole mode, press the F1 key, the tadpole starts to make swimming movements. Press the keys F3 and F4 to control the direction of swimming of the head.

Reaction to light

The tadpole has a cluster of photosensitive cells in the head region in the early period of development. This eye allows you to orient yourself to the animal in whether it is above the open space, or under the shadow of natural fences. To survive the tadpole it matters whether it hides the gaze of predators and animals hunted by it. Therefore, the activity of photosensitive cells influences the behavior of the tadpole, under the influence of light, the tadpole is more active, seeking to escape into the shadows, and the tadpole tends to die in the darkness and safety.

In simulation mode, the light can be turned on and off with the F5 key, in the editor mode, the Z key can control the activity of the receptor responsive to light.

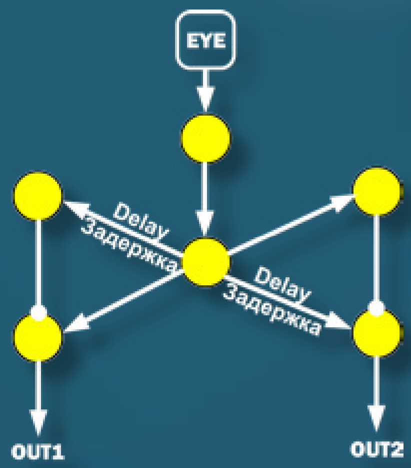
On the example of a reaction to light, we consider several neural circuits that can be used in various aspects of the complex behavior of the animal.

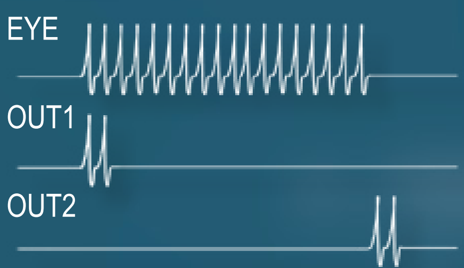
Part_03

In conservation Part_03, light has a modulating effect on motor neurons. When the light is turned on, the amplitude of motor motor movements increases, which leads to greater activity of the tadpole under light.

Start Part_03 in SimWorldTadpole mode, press the F1 key, the tadpole starts to make swimming movements. Turn on the light with the F5 key, the tadpole will swim more actively. Turn off the light by pressing the F5 key again, the tadpole should return to the normal form of swimming.

Part_04



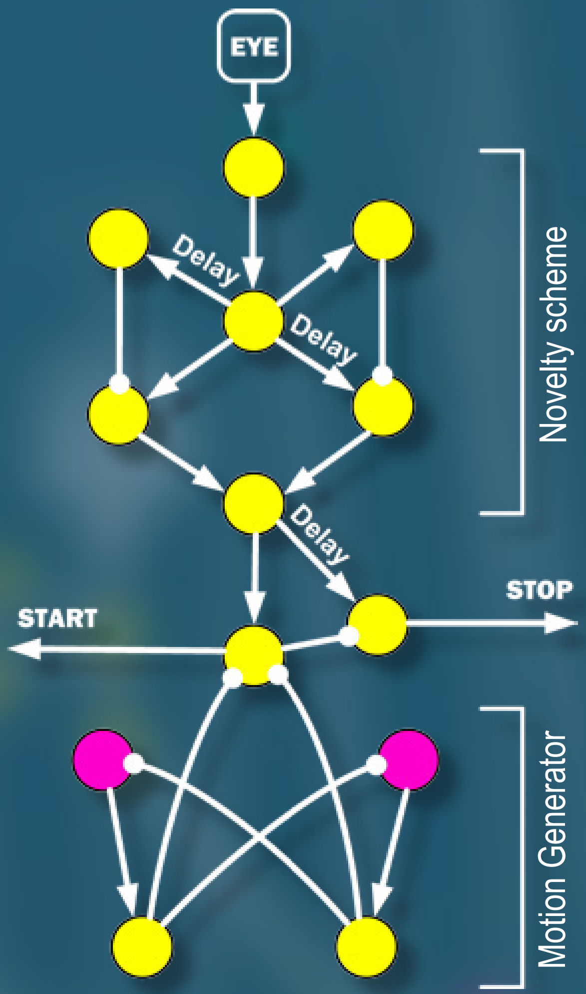


To the tadpole reacted to the fact of switching on or off the light, the following neural circuit can be applied. Scheme with subsequent braking: a continuous stimulus signal will be inhibited by a delayed signal, which at the output leads to a signal only at the beginning of a series of pulses. The circuit with the previous braking: the braking is ahead of the stimulus and at the same time the inhibition ends before the series is pulsed, so the output will be signal only after the end of the pulses.

To react to the fact of change in the operation of photosensitive receptors, it is possible to combine the outputs of these two circuits.

Start Part_03 in SimWorldTadpole mode, turn on the light with the F5 key, the tadpole will start swimming movements. Turn off the light by pressing F5 again, the tadpole stops swimming.

Part_05



The neuronal scheme of novelty allows to receive a signal at any changes in the operation of photosensitive receptors. To change in the environment, the animal responds by changing its behavior. So the tadpole can change swimming at rest, and rest for swimming with changing lighting, this logic can be provided at the expense of two neurons. When the motion generator works, one neuron from this chain will be inhibited, and if it receives a signal from the novelty scheme it will not be activated, but a neuron will be activated which will transmit a signal to stop the generator of motion. In the case of the motion generator not operating, the signal from the novelty scheme will activate the neuron triggering the motion generator and simultaneously inhibit the neuron starting the stopping of the motion generator circuit.

Run Part_05 in SimWorldTadpole mode, force the tadpole to move with the F1 key and stop the tadpole with the F2 key, and also change the lighting mode with the F5 key to affect the behavior of the tadpoles

Thanks to the knowledge of the logic of the work of neurons, you can describe any complex behavior. Try to create a neural circuit, in which the tadpole would react only to the inclusion of light three times.

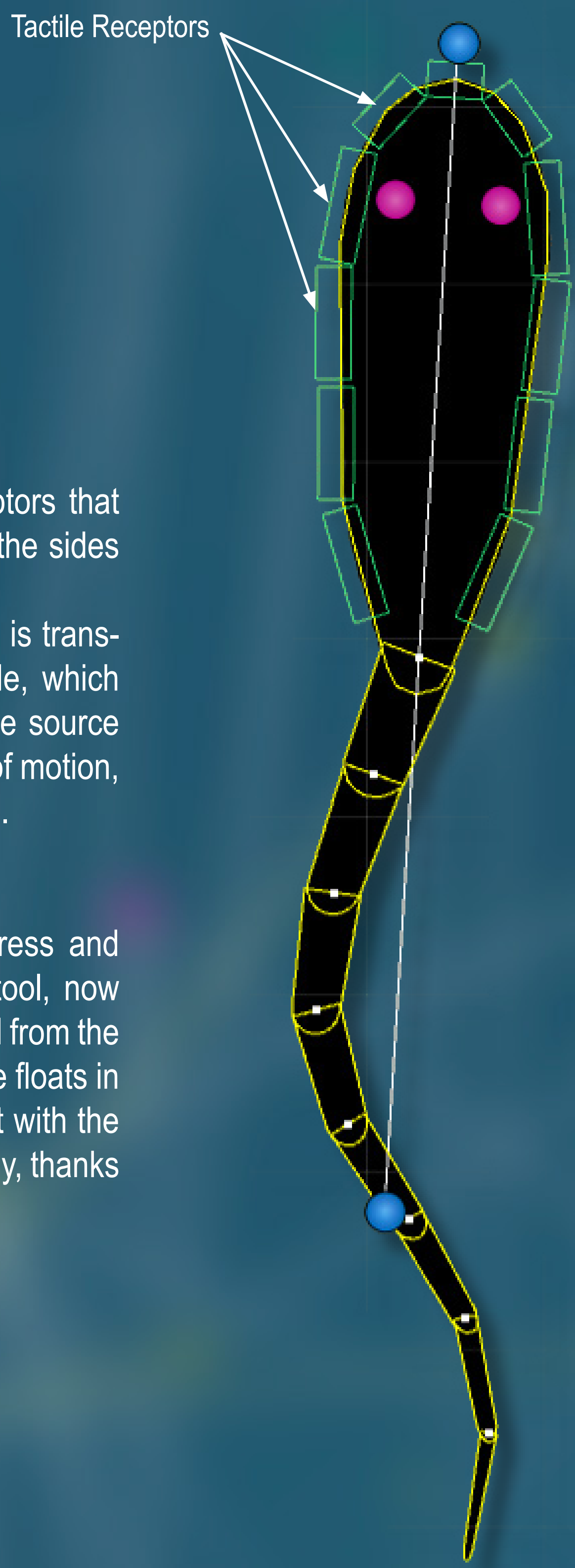
Part_06

In this conservation, the tadpole is calmer in the absence of light, under these conditions it will stop, and freeze, with the light on, this will not happen.

Start Part_06 in SimWorldTadpole mode, press the F1 key, the tadpole starts to make swimming movements, but after a while stop. Turn on the light with the F5 key, initiate the motor activity of the tadpole with the F1 key, the tadpole will not stop automatically when the light is on.

Touch

Part_07



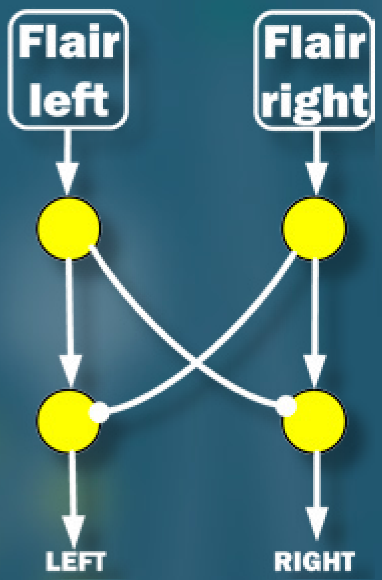
At the head of the tadpole are tactile receptors that react to contact with the instrument “finger” and the sides of the aquarium. Only 11 receptors.

Nervous excitation from the tactile receptors is transmitted to the motor neurons of the opposite side, which would be a powerful movement to recoil from the source of stimulation, as well as to trigger the generator of motion, that would swim away from the source of irritation.

Run Part_02 in SimWorldTadpole mode, press and hold the left mouse button, calling the “finger” tool, now touch the tadpole’s head, the tadpole should recoil from the “finger” and begin to swim. Watch how the tadpole floats in the aquarium, avoiding its walls. Turn on the light with the F5 key, the tadpole will begin to swim more actively, thanks to the modulation effect in its nervous system.

Smelling

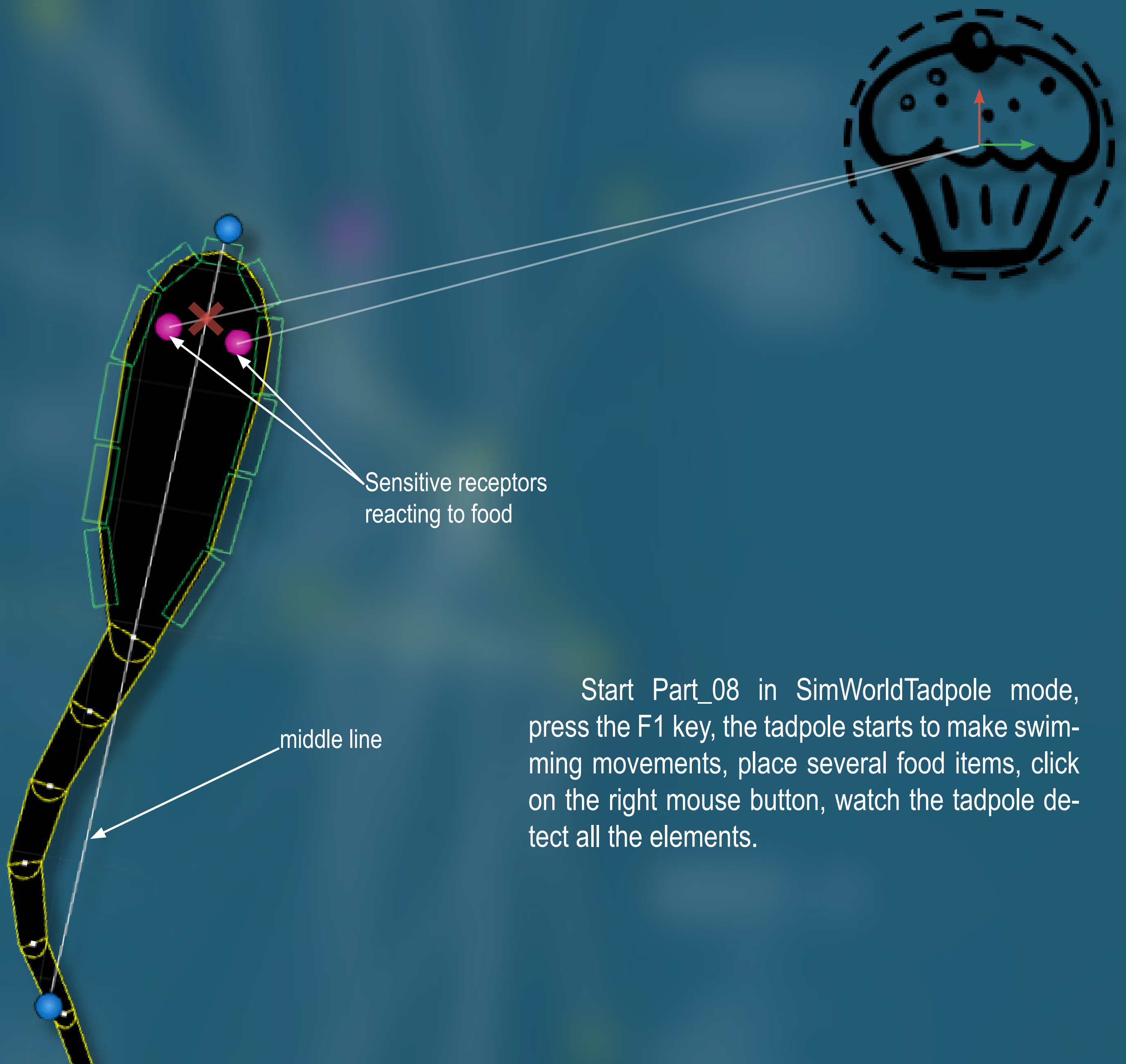
Part_08



The tadpole has two sensitive receptors that react to food, the closer the food, the more intense the activity of the recipe will be, taking into account the square of the distance to the meal, but if the food and the sensitive receptor connect the line crossing the middle line, then the sensitive receptor will not be React to this food.

To properly process information from two food-sensing receptors, signals from them must undergo a neural scheme of mutual inhibition.

The element of water disappears as soon as it touches the front of the head of the tadpole.

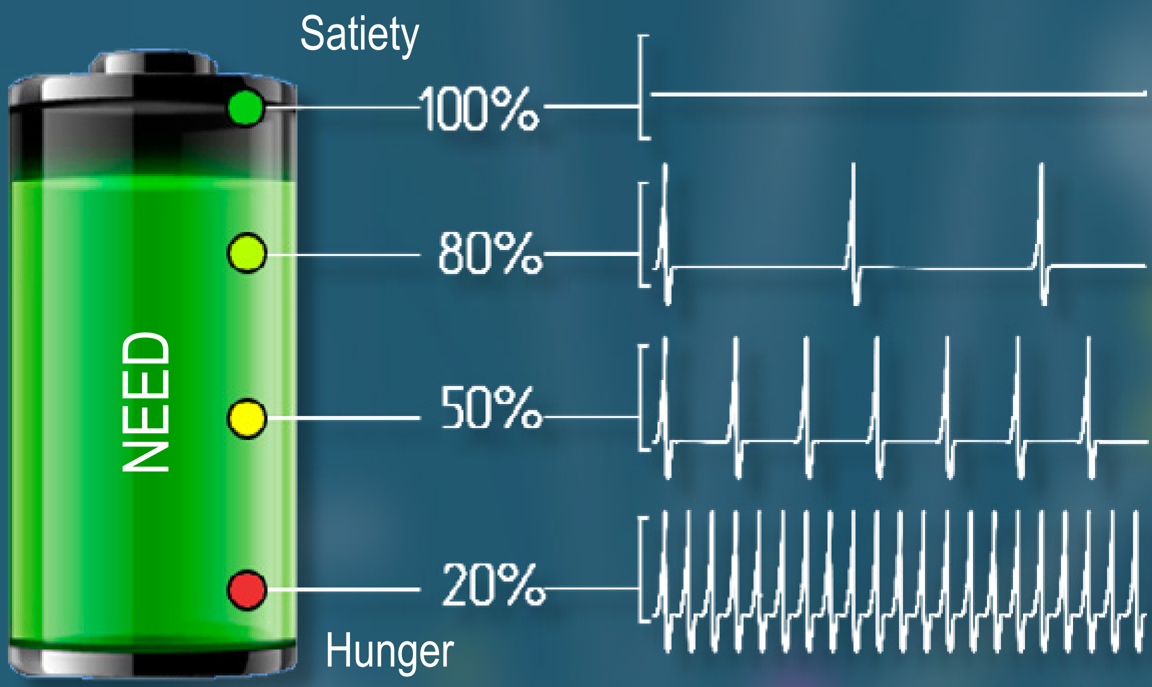


Start Part_08 in SimWorldTadpole mode, press the F1 key, the tadpole starts to make swimming movements, place several food items, click on the right mouse button, watch the tadpole detect all the elements.

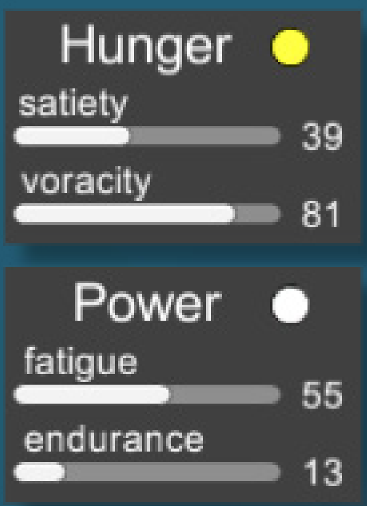
System of needs

The requirements mechanisms are based on the work of specific receptors that are oriented to the level of saturation with a certain need, depending on the level, the intensity of receptor activation will be determined. The lower the saturation level, the higher the intensity of receptor activations.

In the simulator there are two mechanisms of needs: the need for food and the need for rest. It is possible to adjust the speed of data needs and to manage their level directly.



Part_09



In this conservation, the Hunger receptor responsible for feeling hungry controls the modulation of neurons associated with food sensitive receptors. Not a hungry tadpole - practically devoid of sense of smell.

The Power receptor responsible for the need for rest is connected with a chain of neurons suppressing activity in the motion generator.

Run Part_09 in SimWorldTadpole mode, adjust the level of voracity by 80%, and the endurance level by 10%, mark out several elements of the food in the aquarium, watch the activity and search for food replaced by inactivity and rest at the tadpole. Adjust the parameters of the tadpole metabolism at your own discretion.

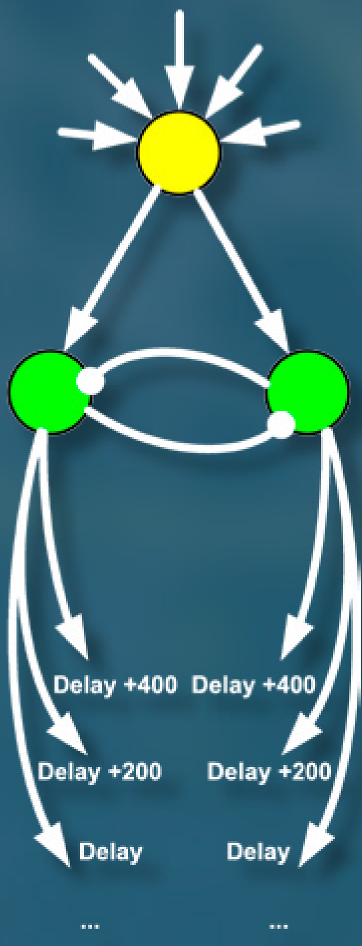
Protective reflex

The “Vise” tool is turned on in the simulation mode with the F6 key, while the head of the tadpole is fixed and the tail is in a free state, so the receptors of the touch will be continuously strong.

Part_10

In the conservation of Part_10, there is a protective reflex, manifested in the fact that when the tactile reflexes are strongly affected, the tadpole begins to make strong long flaps with the tail, and the muscle contraction begins at the end of the tail and spreads to the head part of the tadpole. The tadpole, as if backing away, is trying to free itself from the “vise”.

This reflex is based on a simple neural circuit, the neuron-summator receives signals from the tactile receptors, its threshold determines the degree of activation of the receptors, at which the protective reflex begins to work. In our case, the threshold of the adder is high enough to distinguish the response to a light touch and the reaction to the clamp in the “vise”.



When activated, the adder sends signals to two modulated neurons (green), which are mutually inhibited, which prevents them from being activated simultaneously, so one of them receives a signal from the adder with a small delay. Modulated neurons are tuned so that their mechanism of habituation works with 1,500 repeated activations, then the neuron stops responding to irritation and it takes some time to restore the original parameters. While the effect of the adder acts, the modulated neurons are alternately activated, while they activate the motor neurons of the tail, each on its side. The signal from the modulated neurons comes to the motor neurons of the tail end earlier, and to the front of the tail with a delay.

Run Part_10 in SimWorldTadpole mode, press F6, watch as the tadpole tries to get out of the trap. Press F6 again, the tadpole should remain active for a while and try to swim away from the dangerous place

Saving Part_10 has an optimally complete set of tadpole reflexes available in the OPENTadpol simulator.

OPEN Tadpole

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