EMF hypersensitivity and tissues generating electric current – biological reality

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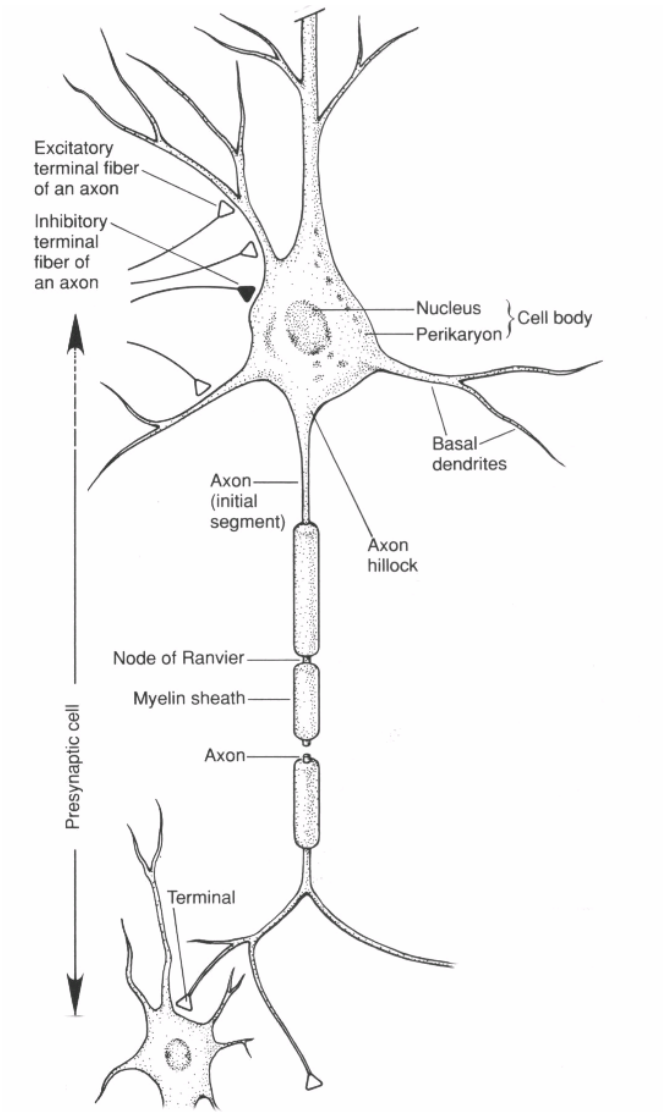
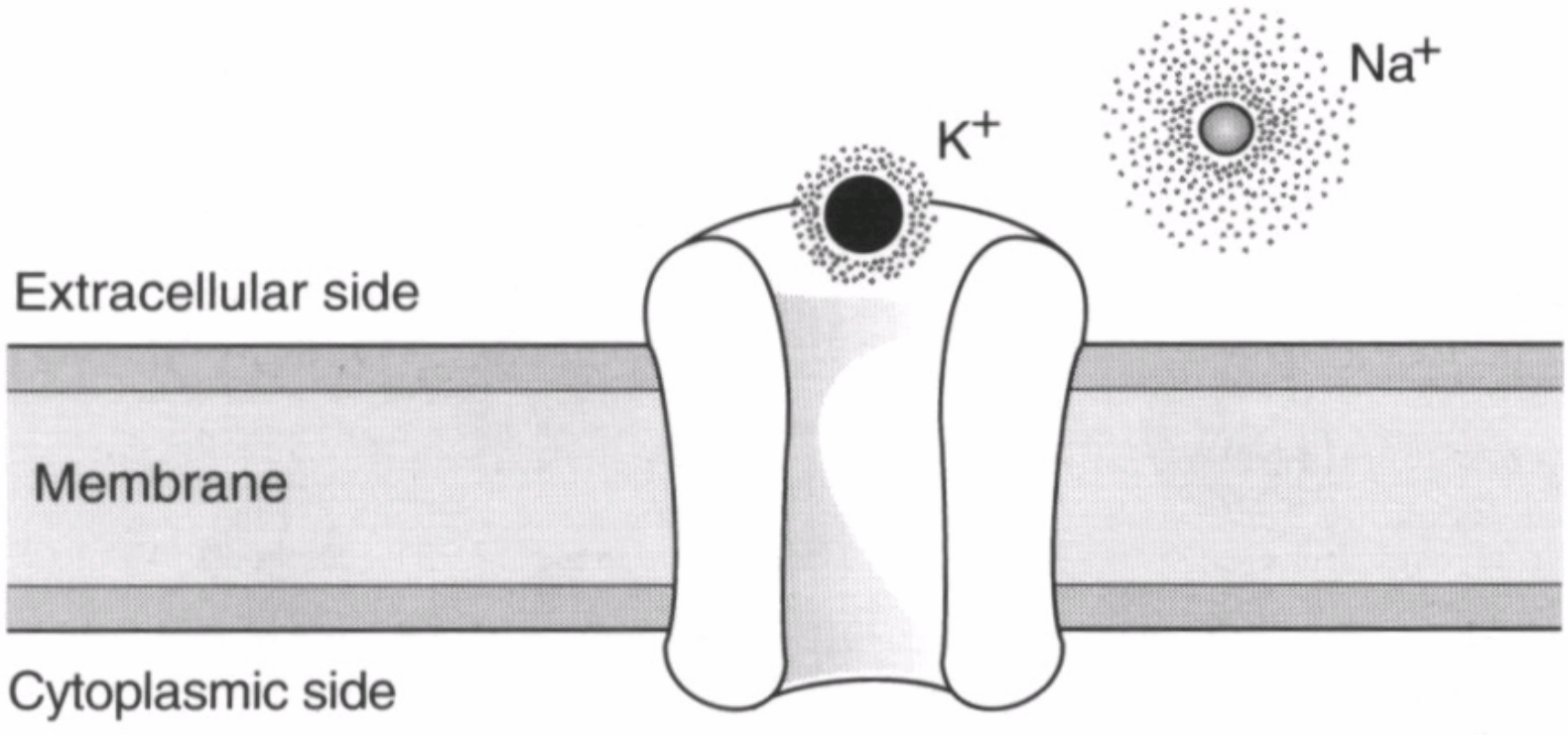
Electric transmission and processing of biological information

- Excitable cells are chemical batteries the charge of which changes from -70 mV at rest to +30 mV during brief activation
- Local decrease of membrane potential by 30 mV opens Na^+permeable channels and elicits action potentials propagating through the axon of the neuron to remote parts of the brain and to extra-cerebral targets (muscles, glands, receptors).
- A neuron receives input from about 10^4 synaptic contacts and its activation needs simultaneous discharge of about 100 synapses

Typical neurons of vertebrate brain



Lipid bilayer with an ion channel

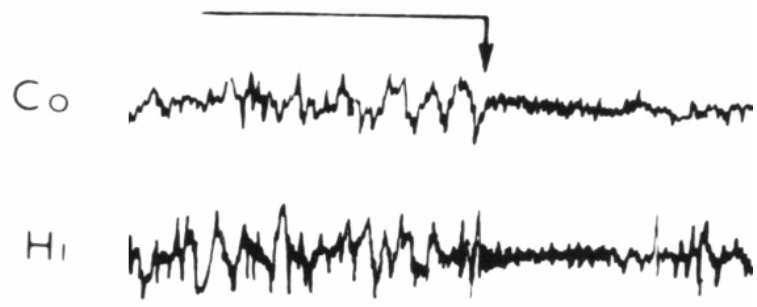


Quantitative characteristics of the neural network of the human brain

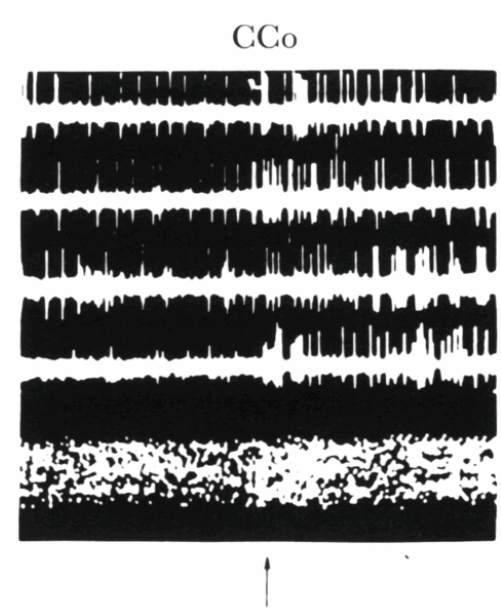
- The 10^{11} neurons forming the human brain are joined by 10^{14} synapses into a network
- At any moment about 1% of neurons are active and generate each second 10^{9} action potentials which expose the brain to a deluge of randomly distributed pico- and micro-A currents
- This inherent electric noise with amplitude of 10 to 100 uV and field intensities of 1V/1m does not interfere with the highest cognitive and executive functions of our brain

Electrical activity recorded with

Large electrodes (EEG)



Microelectrodes (unit activity)



Medical use of technically produced electric stimuli

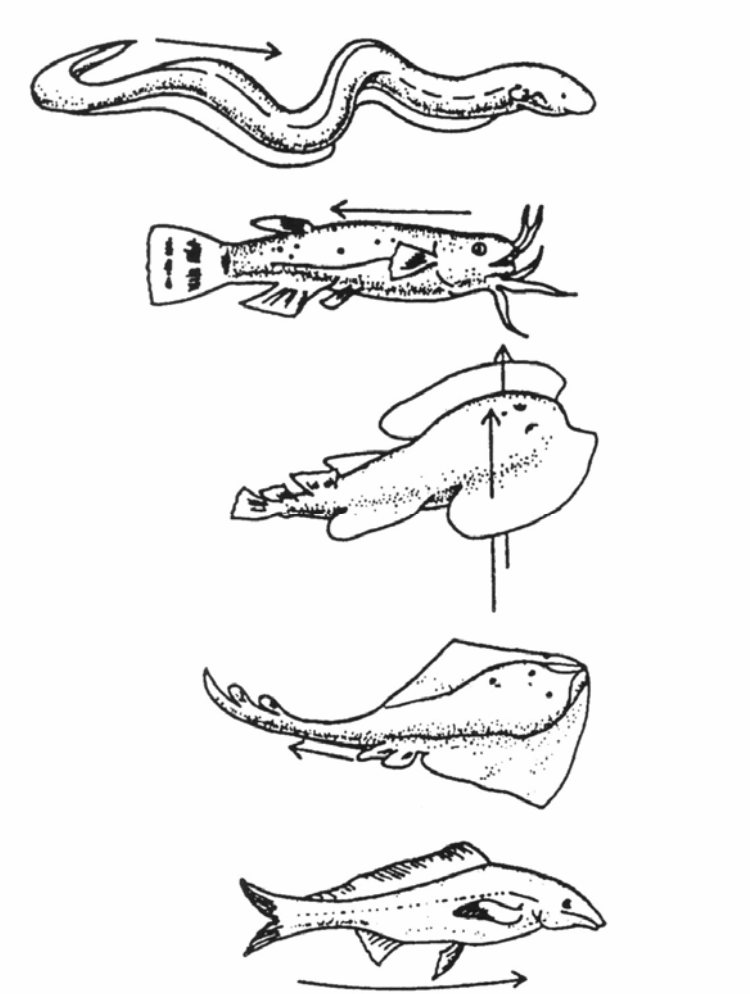
- Electric current (10^{-6} to 10^{-2} A) is employed for stimulation or blockade of excitable tissues in many therapeutic and diagnostic applications.
- Single shock to fibrillating heart can save human life (defibrillation). Permanent stimulation by implanted pacemakers cures cardiac block or severe arhythmia.
- Application of 10^{-5} A current to electrodes in the hypothalamus of rats elicits pleasure manifested by self-administration of such stimuli. Stimulation of thalamus of Parkinson patients alleviates their tremor, rigidity and difficult walking.

Biological generation of higher electric field intensities

Series summation of emfs of thousands of individual cells in electric organs of marine or fresh-water electric fish can generate discharges of up to 700 V and 10 A, used for stunning prey or for predator defense.

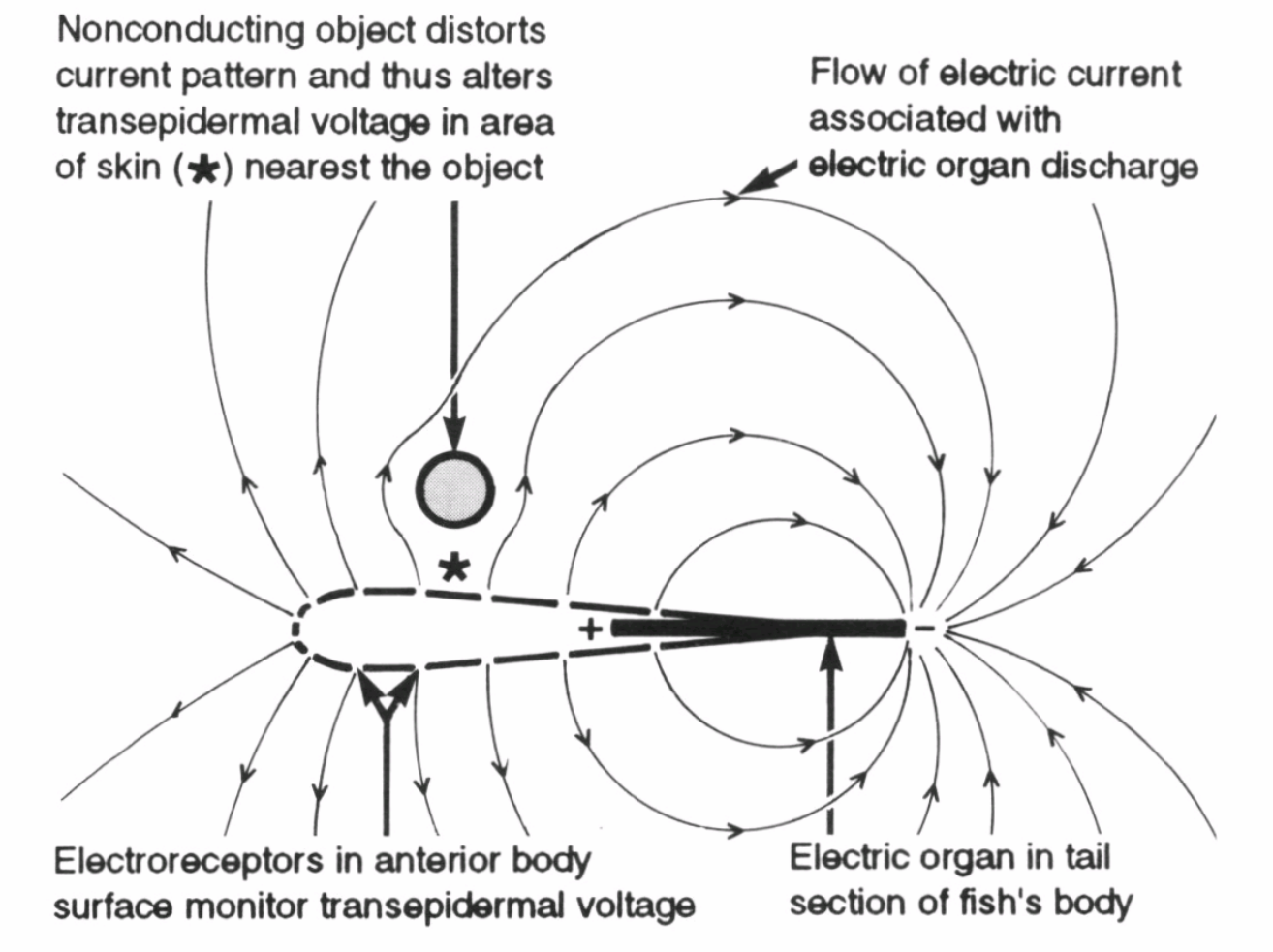
Electric fish

- Electrophorus electricus
- Malapterusus
- Torpedo
- Raja
- Mormyrus



Weakly electric fish combine continuous ~10 V discharge of electric organ and activity of electroreceptors in the lateral line system for sensing the electric field they generate in ambient water and for locating thus areas of higher or lower conductance.

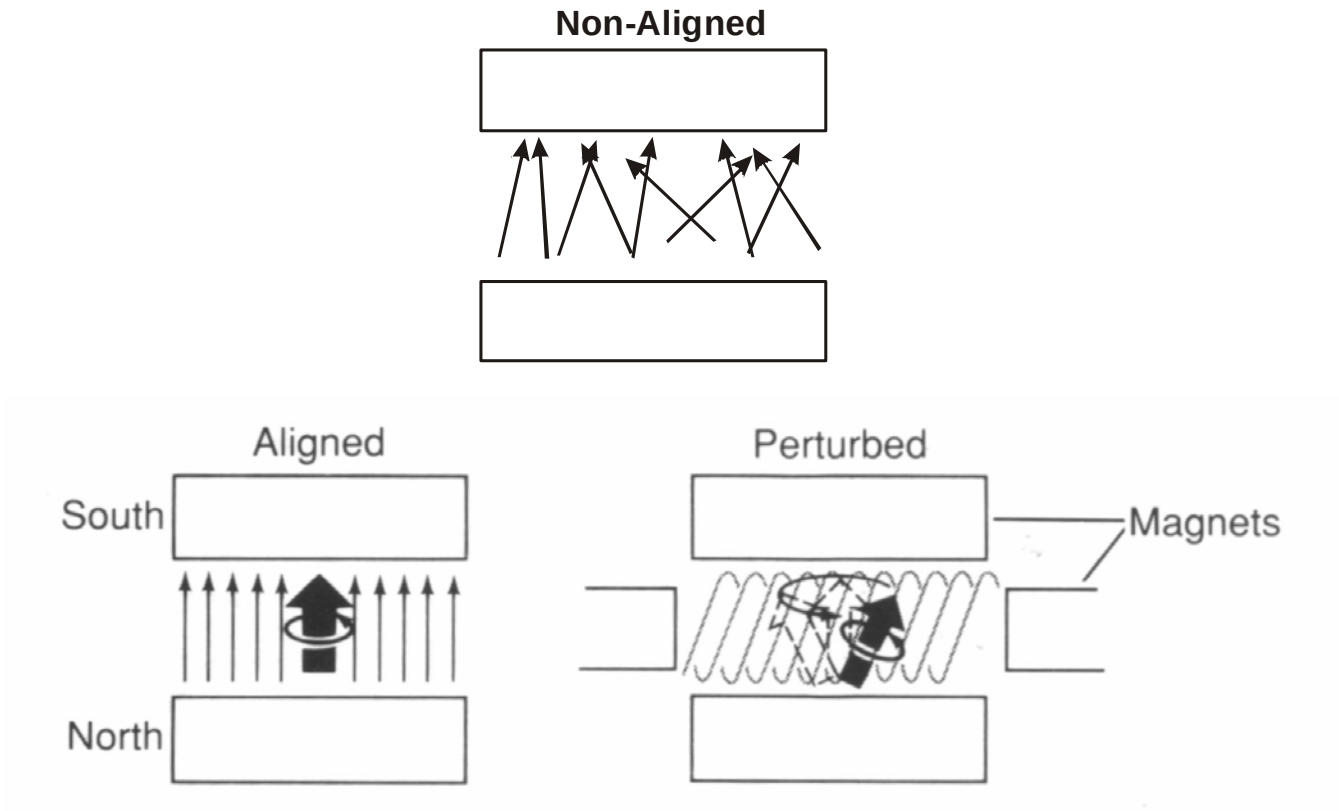
Electrolocation in a weak electric fish Gnathonemus petersii



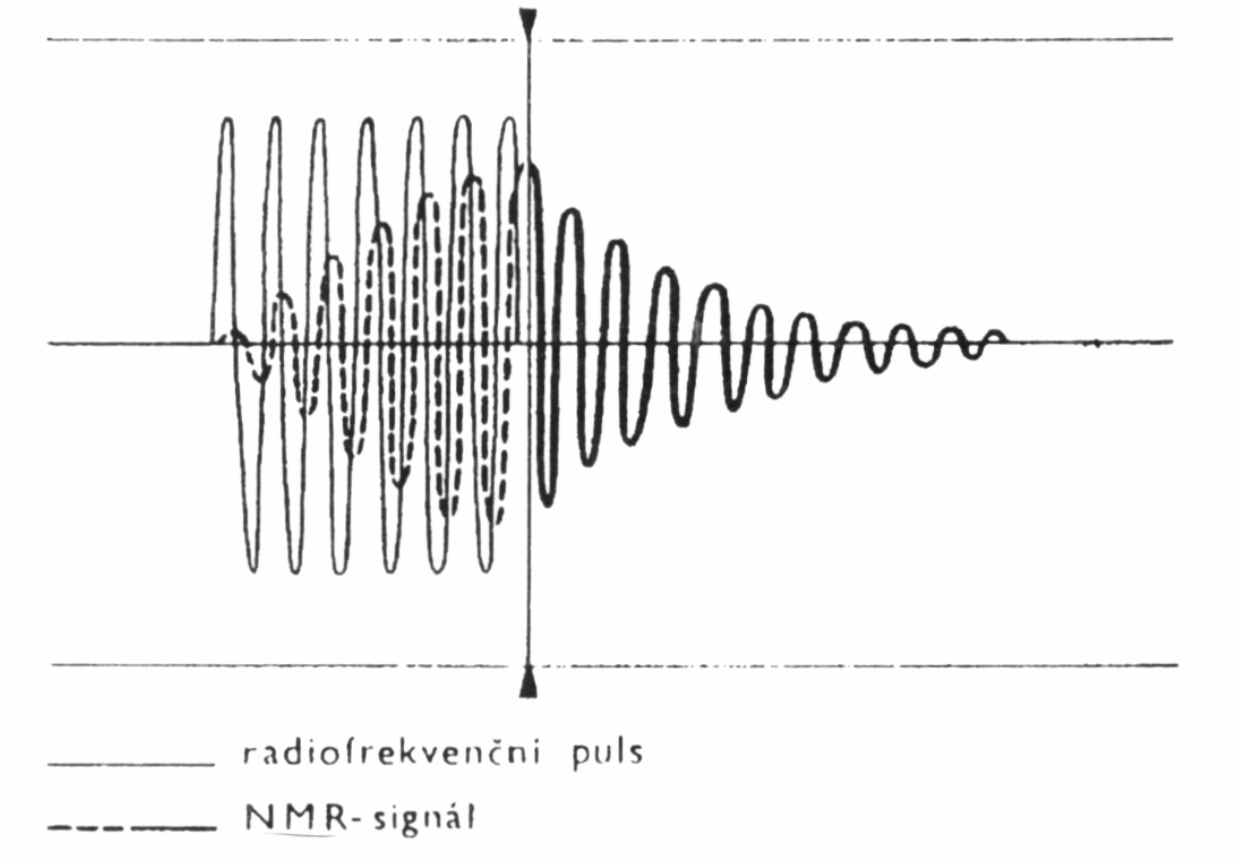
Biological effects of magnetic fields

Although subterranean mammals are able to use natural magnetic field of 50 uT for orienting underground tunnels, 10^5 times stronger static fields used in several hours long NMR (nuclear magnetic resonance) examinations in patients are imperceptible and evoke no noxious or disturbing effects

NMR - nuclear magnetic resonance



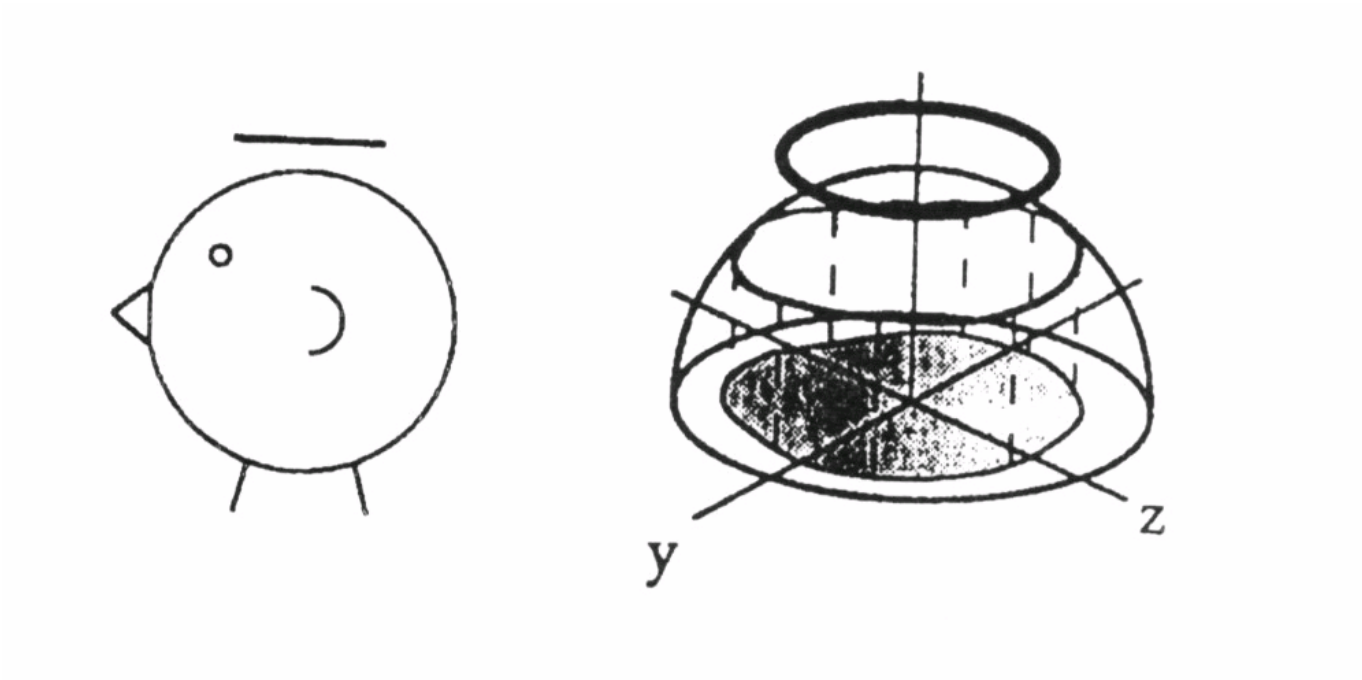
Oscillation of the aligned molecules evoked by radiofrequency pulses continues in the interval between them and indicates thus the brain loci with their maximum concentration.



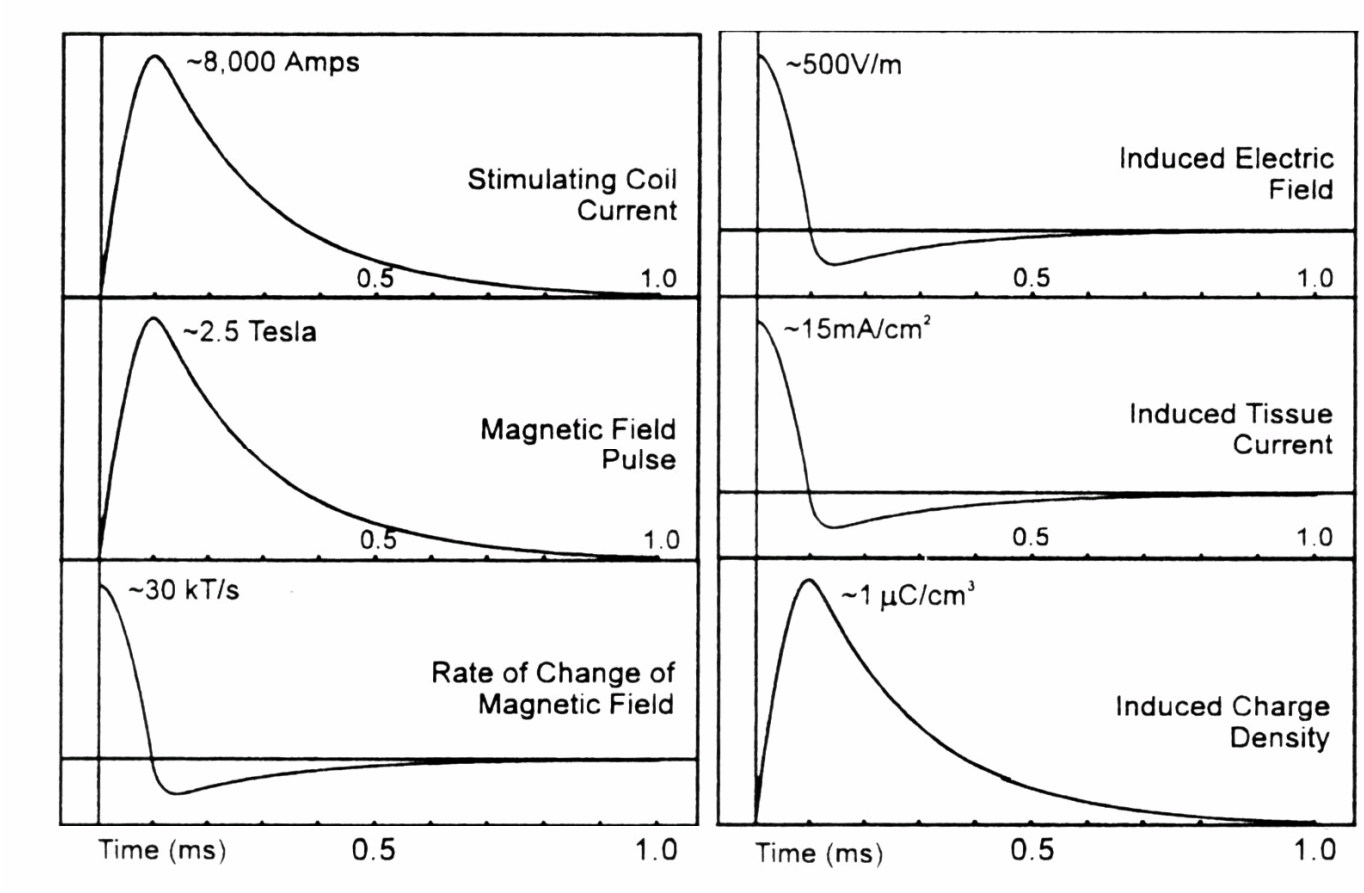
Biological effects of magnetic fields

Short (1ms) 2T pulses evoked by passing 10^4A current through a coil applied to head induce in the brain tissue 10 mA/cm^2 currents stimulating or blocking selected centers, but causing no damage.

Transcranial magnetic stimulation - scheme of apparatus



Brief extra-cranial magnetic pulse induces electric current in brain



Conclusions

- Nervous system is build in a way eliminating influence of intrinsic noise and of common sources of external EMF on signal transmission and processing in the brain
- Promising medical applications require direct connection of outputs and inputs of technical devices to relevant brain circuits.
- The aim of biomedical studies is not to eliminate interaction of external EMF with brain but to develop its safe and reliable forms indispensable for effective brain-computer interaction.