

Stereotaxis

Stereotaxis

= a method that allows targeting individual brain structures using external orientation points and dimensions of the skull

– minimum invasive neurosurgical method

History

- Origin of human stereotaxic neurosurgery:
 - a stereotaxic apparatus by Spiegel and Wycis 1946
- The 1st stereotaxic surgery in 1947: stereotaxic administration of ethanol into the globus pallidum and medial thalamus in a patient with the Huntington's chorea
- During the seventies: coagulation of the amygdale in epileptic patients with psychoemotional disorders

Principles of the method

- Exact targeting of particular structures deep in the brain
- No need of direct visual control
- Before the surgery: localization of the target and measurement of its position using a stereotaxic frame and imaging methods
- Determination of stereotaxic coordinates of the brain structure in a system of 3 perpendicular plains
- Coordinates: X, Y, Z – exact definition of the position inside the intracranial space

In humans, exact stereotaxic coordinates are found using neuroimaging methods for each individual patient.

For laboratory animals, the coordinates can be found in an stereotaxic atlas. In its index, e find an abbreviation that represent structure of our interest. In the next index organized according to the alphabetic order of the abbreviations, we the page (pages) where the structure is depicted. Some atlases show frontal, sagittal as well as horizontal sections. Therefore, the index mostly provides more pages for each structure. For each structure a different plain of the section can be the most illustrative. Depending on their size, the structures can be depicted on more subsequent pages (then the index provides arrange of the pages).

According to the section plain orientation, each page represents a section of a particular coordinate in the appropriate direction (see later). This information is written on each page. The later 2 coordinates have to be found using the coordinate network.

The basic reference point (having all 3 coordinates = 0) is the bregma (the intersection of the coronal suture and sagital suture . As an alternative reference, the interaural line (connecting the left and right meatus acusticus) can be used.

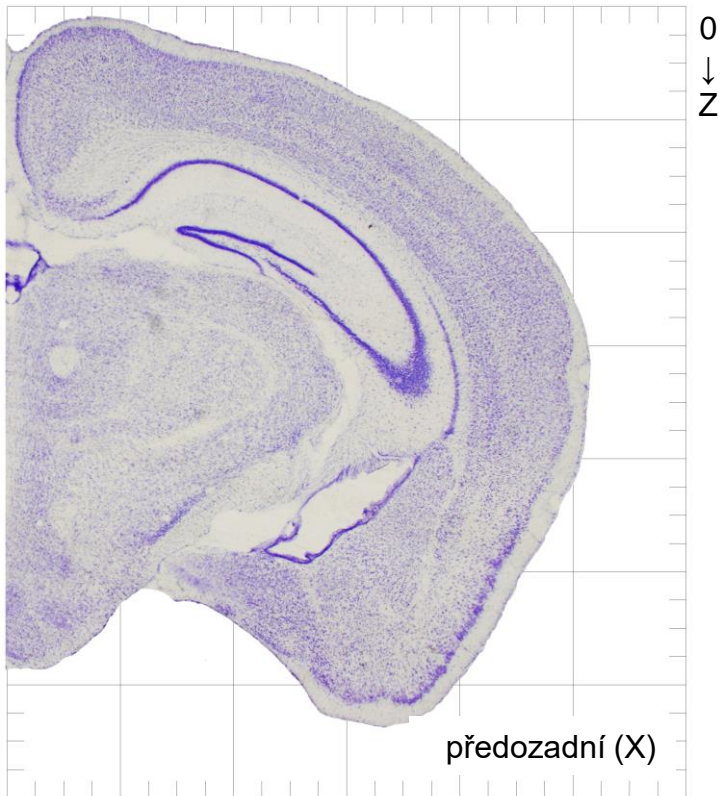
Orientation in the stereotaxic atlas

3 coordinates (reference = bregma): X = antero-posterior, Y = lateral, Z = vertical

Frontal sections

X-coordinate is written on each page; Y- and Z-coordinates are found using the network.

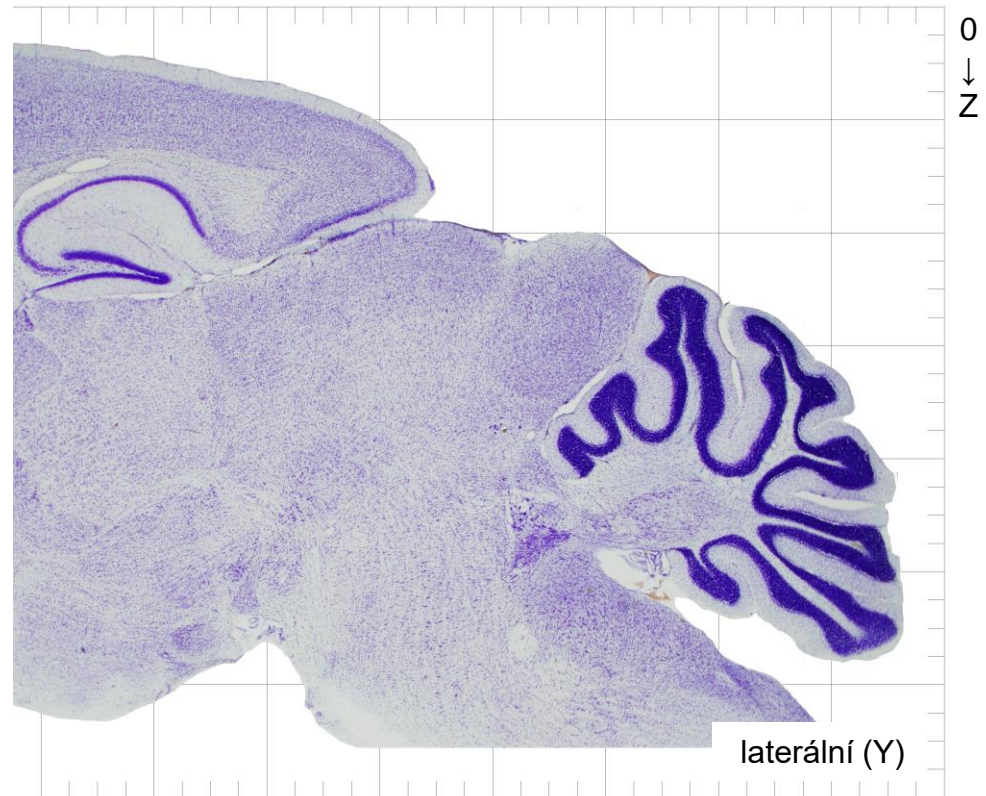
0 → Y



Sagittal sections

Y-coordinate is written on each page; X- and Z-coordinates are found using the network.

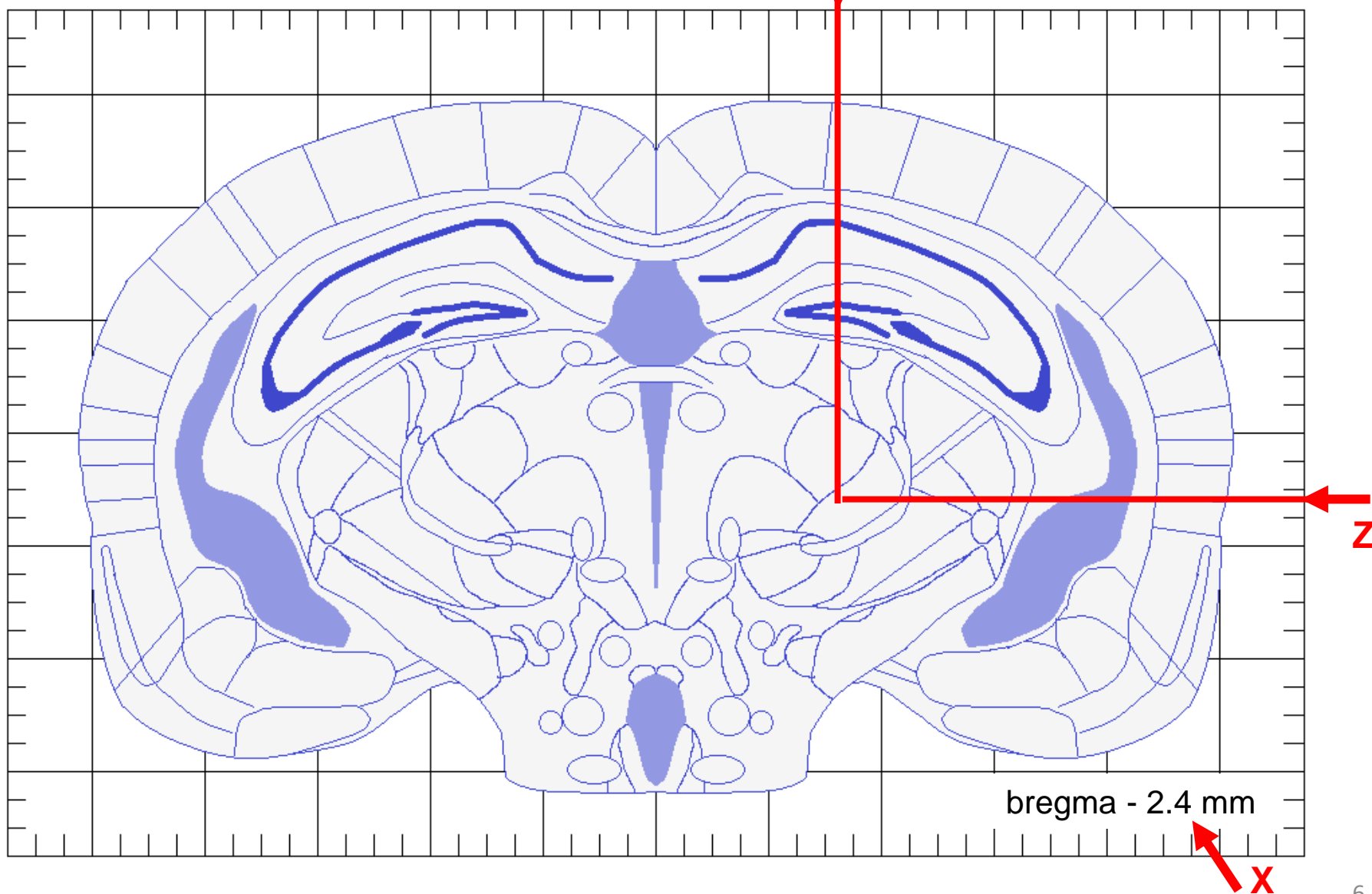
0 → X



Horizontal sections:

Z-coordinate is written on each page; X- and Y-coordinates are found using the network.

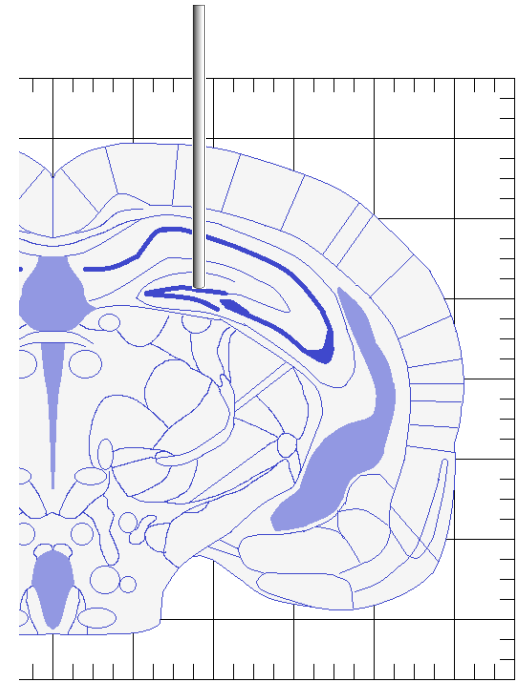
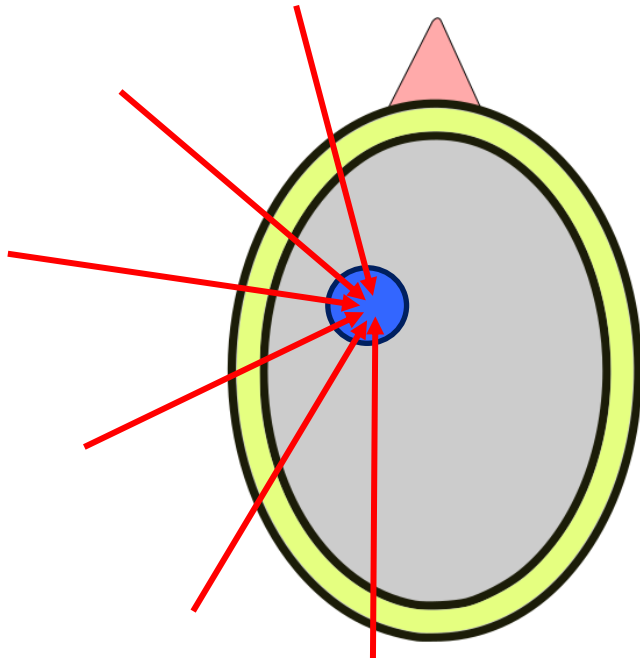
VPM = ventral posteromedial thalamic nucleus
X = -2,4 mm, Y = 1,6 mm, Z = 3,6 mm



Types of manipulations in targetted area

- instruments that are introduced

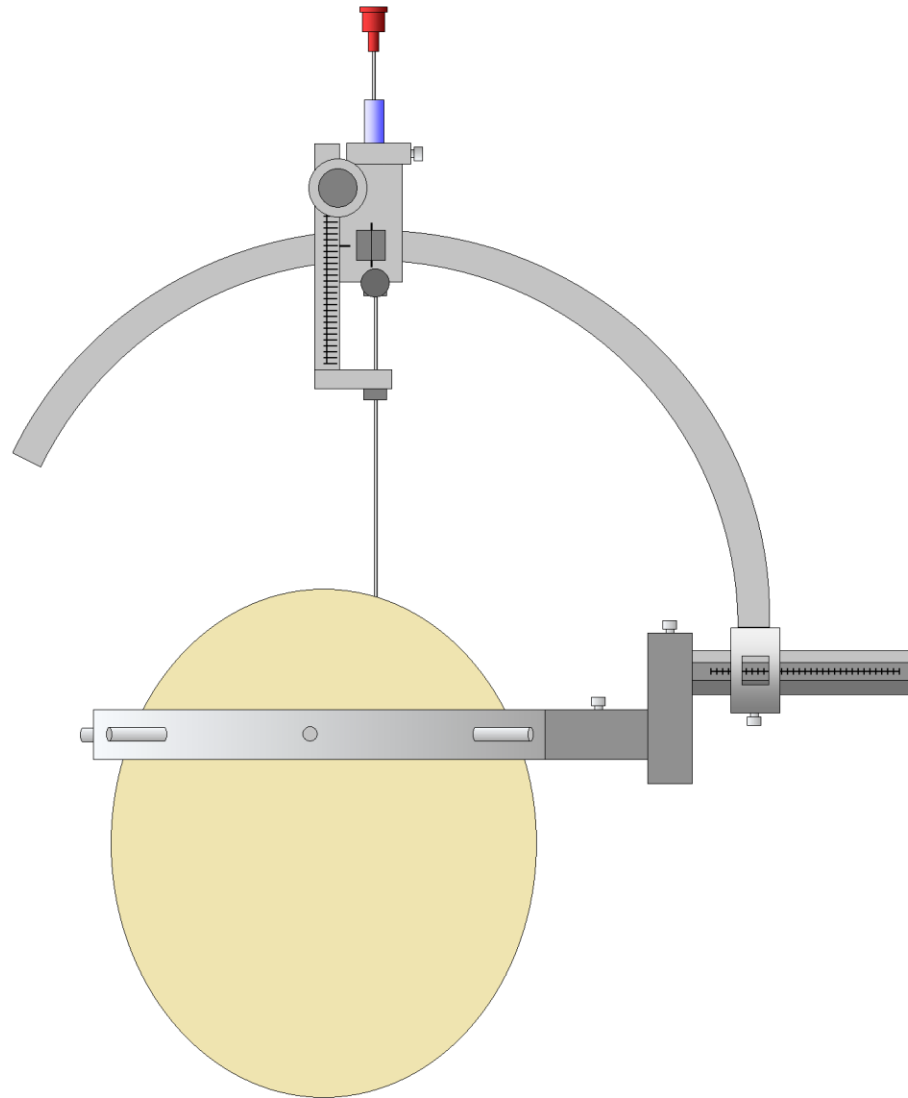
- Registration electrode
- Stimulation electrode
- Electrocoagulation electrode
- Cannula for substance/cell administration
- Biopsy needle
- Beam targeting (the Leksell gamma knife)



Stereotaxic frame for laboratory rodents



A schematic example of a stereotaxic frame for humans



Applications of stereotaxis

- „Extrapyramidal“ movement disorders (basal ganglia): the Parkinson disease, essential tremor, various forms of dystonia
- Pain elimination (lesions or stimulation of certain thalamic nuclei)
- Intracranial expansive processes treatment (pituitary tumors, vascular malformations, solitary metastases)

Treatment of „extrapyramidal“ disorders

- Reduction of symptoms by targeted manipulation
- Elimination of certain structures of the basal ganglia: destruction, electrostimulation
- **Destruction:** thermocoagulation by electric current administered via an stereotaxic electrode (60 – 75 °C)
- neurotransplantation

Chronic deep brain stimulation (DBS)

- Stimulation of the basal ganglia by electric pulses leads to reduction of tremor in the Parkinson disease (known since the sixties of the 20th century) – only transient effect during the stimulation
- Electrodes suitable for permanent implantation into the brain – permanent stimulation of the brain structures (amplitude of 1-4 V, frequency of 130-160 Hz)
- Neuromodulation!, no destruction of the brain tissue, functional stereotaxic surgery

The course of stereotaxic operation

- Cooperation with the patient is necessary – only local anesthesia
- Mounting of a stereotaxic frame on the head (fixation by screws in local anesthesia to the surface of the skull bones)
- Examination with MR, calculation of stereotaxic coordinates of the target brain structure
- Drilling the skull, insertion of an electrode for DBS
- Diagnostic stimulation by an electrode, registration of neuronal activity specific for given nuclei
- Insertion of a permanent electrode
- Implantation of a neurostimulator under the skin below the clavicle (connected with the stimulator by an cable in a subcutaneous channel)

Advantages of the method

- Indications: When pharmacological treatment of the Parkinson's disease is not effective
- The stimulation can suppress all basal Parkinsonian symptoms
- Reduction of the need of pharmacotherapy
- The effect of DBS is long-lasting (batteries of the stimulator for 5 years, then only exchange of the subcutaneous part of the system)
- Improvement of the patient's abilities, improvement of daily life activities
- The mechanism of DBS effect?, a hypothesis: induced functional changes, the nucleus is forced to work with a different frequency of burning of its neurons – transferred to other structures