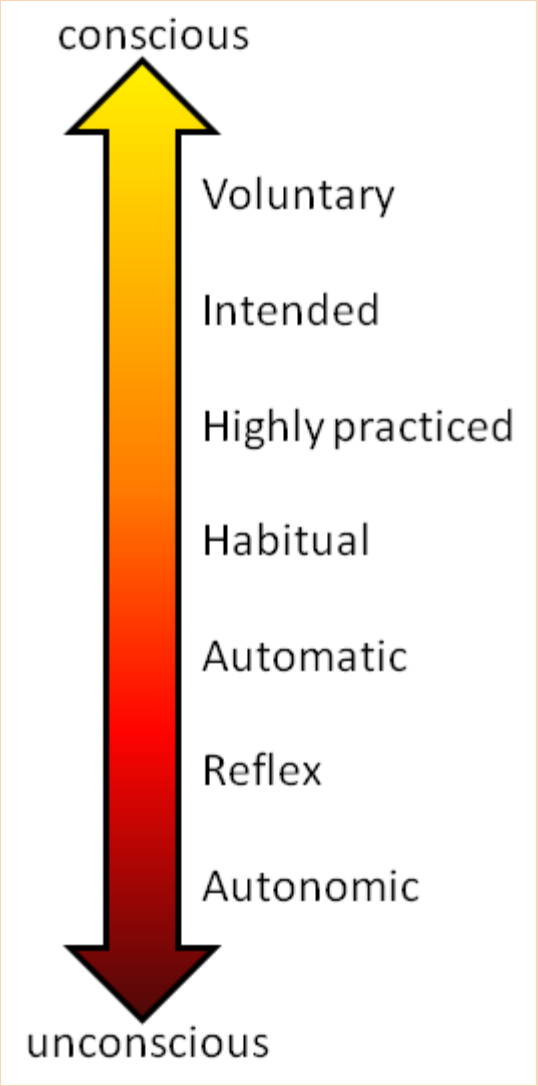
Different levels of Control



Staged vs. Spontaneous Movements

Lecture 1 (Week 3)

Autonomous
Spontaneous-
self emerging
Temporally optimal

Intended
Goal driven
Spatially optimal

INSTRUMENTAL ACTS

REACHING, GRASPING, POINTING, REQUIRE ON-LINE GUIDANCE, ATTENTION, INTENDED vs. AUTOMATED

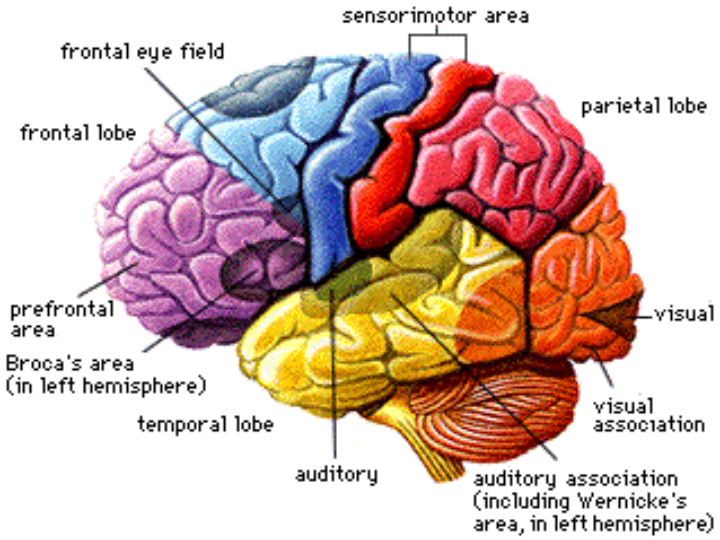
The bulk of motor research In Neuroscience

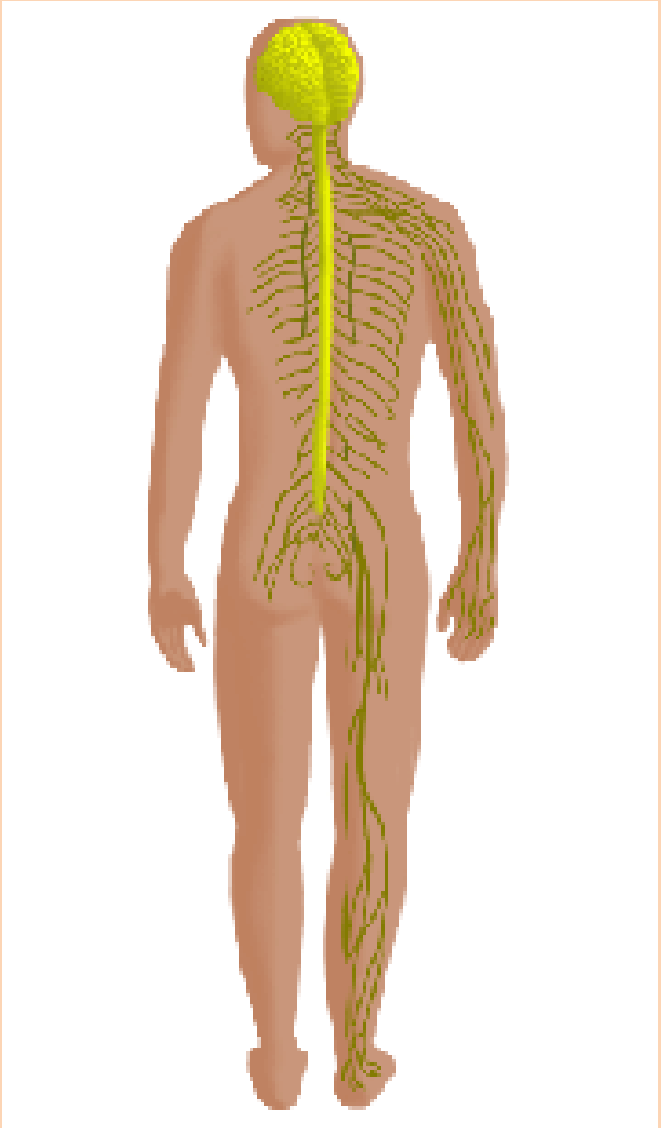
COMPLEX ACTS: GESTURE + SPEECH; CHOREOGRAPHED ROUTINES

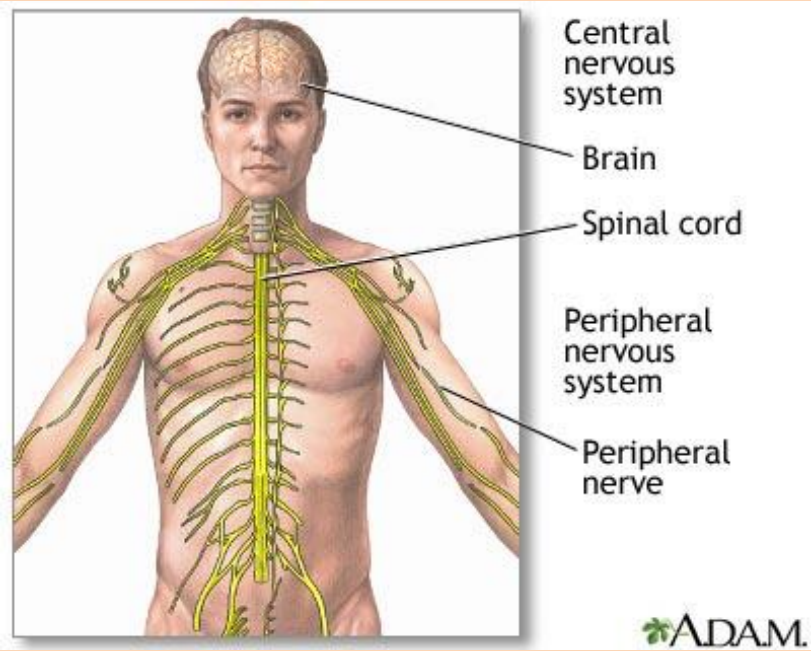
REQUIRE SIMULTANEOUS COORDINATION OF MULTIPLE LIMBS, HEAD, TRUNK, STAGED vs. SPONTANEOUS

Motor related research in Psychology (Language, Cognition) and Sports (Movement) Science, Rhythmic motions

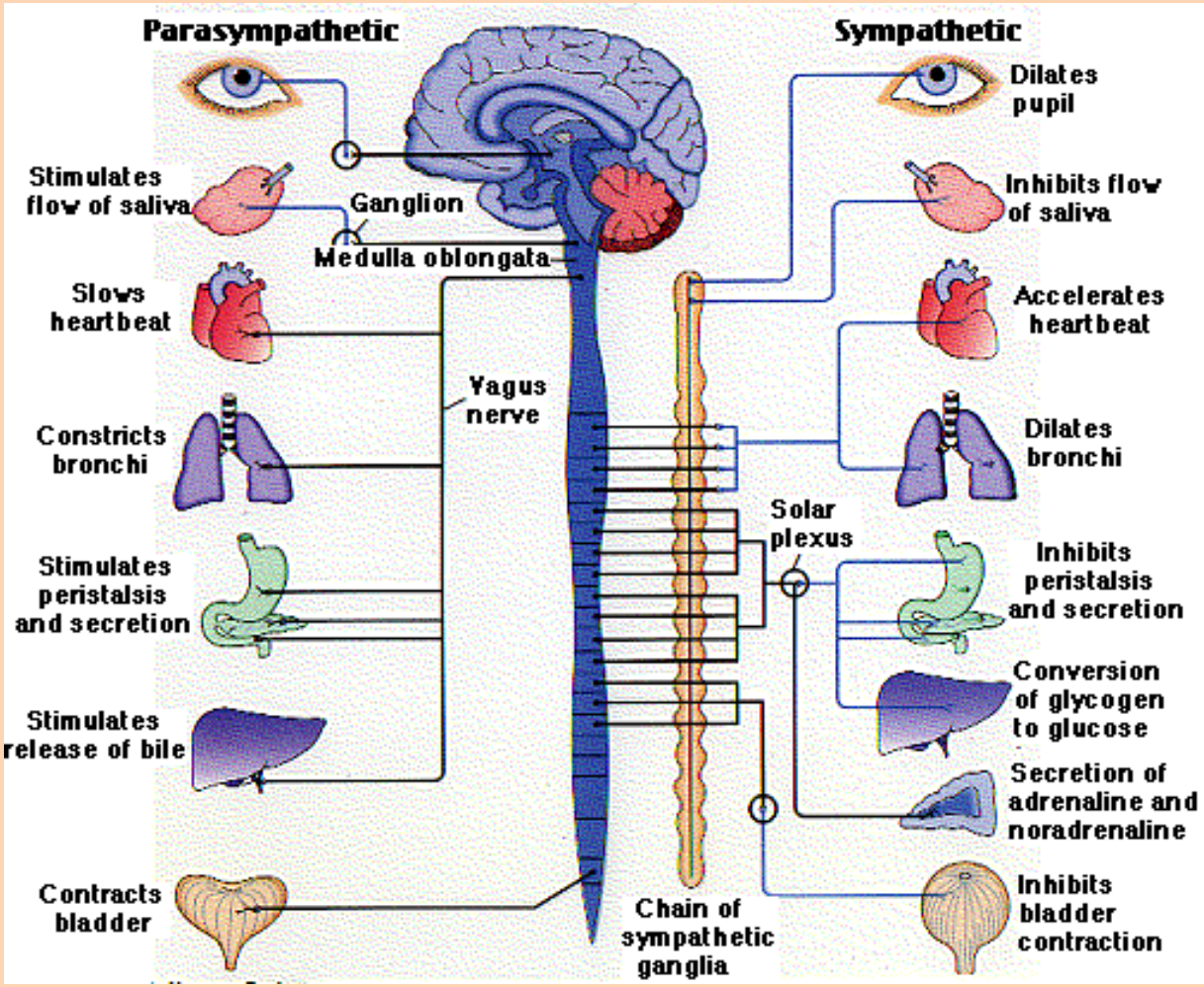
CENTRAL AND PERIPHERAL NERVOUS SYSTEMS



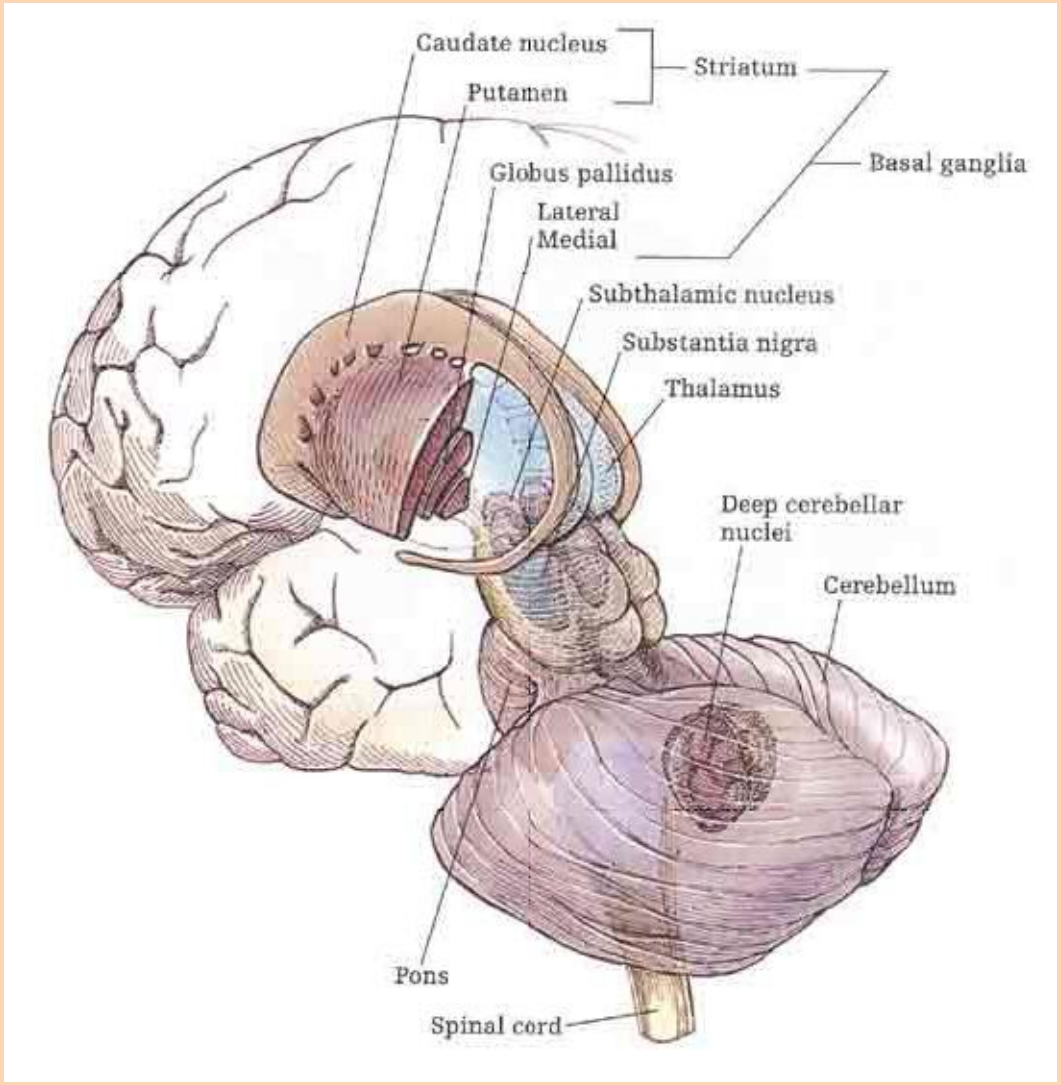




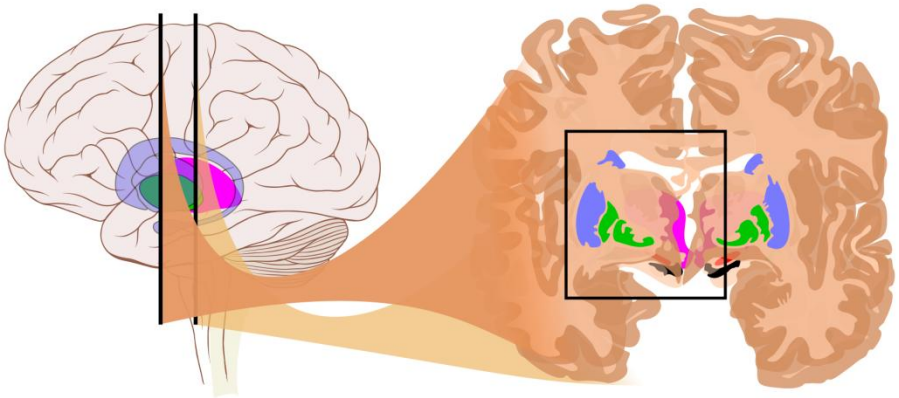
AUTONOMIC FUNCTIONS

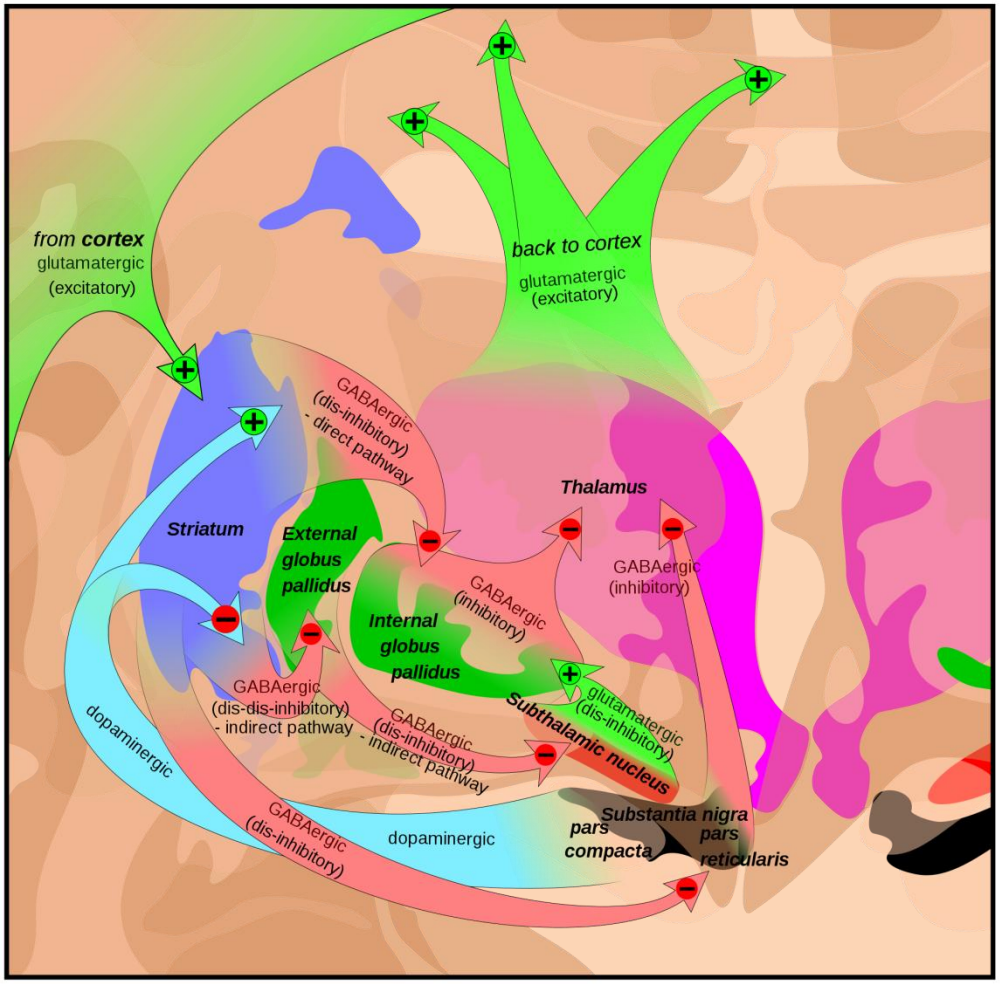


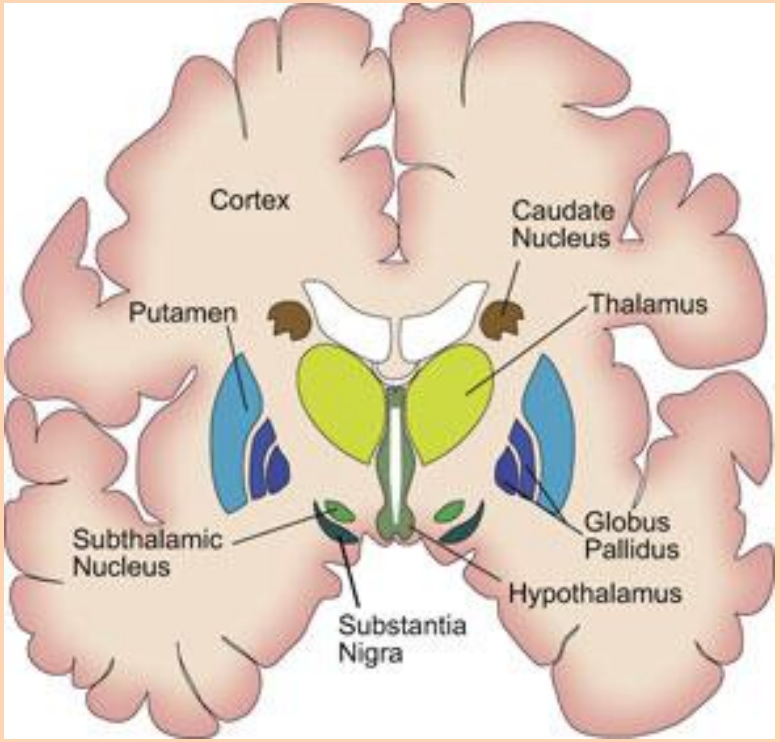
The Limbic System
Automated Motor Programs and Autonomic Functions



Basal Ganglia Circuitry







Neurotransmitters and micro-circuitry

In the Basal Ganglia the great majority of neurons use GABA as neurotransmitter and have inhibitory effects on their targets.

The inputs from the cortex and thalamus to the striatum and STN are glutamatergic, but the outputs from the striatum, pallidum, and substantia nigra *pars reticulata* all use GABA. Thus, following the initial excitation of the striatum, the internal dynamics of the basal ganglia are dominated by inhibition and disinhibition.

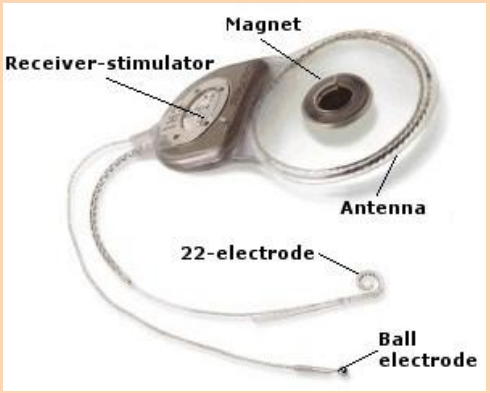
Other neurotransmitters have important modulatory effects. The most intensively studied is dopamine, which is used by the projection from the substantia nigra *pars compacta* to the striatum, and also in the analogous projection from the ventral tegmental area to the nucleus accumbens.

Acetylcholine also plays an important role, being used both by several external inputs to the striatum, and by a group of striatal interneurons. Although cholinergic cells make up only a small fraction of the total population, the striatum has one of the highest acetylcholine concentrations of any brain structure.

DEEP BRAIN STIMULATION TO TREAT TOURETTES SYNDROME

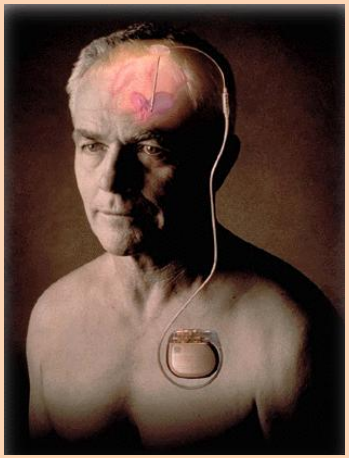
Impact of Neural Interfaces

Neural interfaces have already provided substantial benefits to individuals.



Cochlear Ltd. Nucleus® 24 cochlear implant system

Cochlear Prosthesis bypasses damaged hair cells in the auditory system by direct electrical stimulation of the auditory nerve.



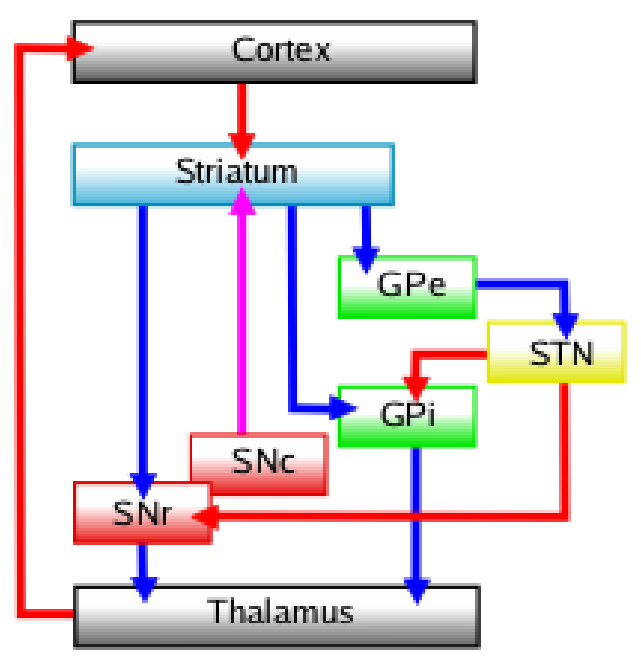
Activa Medtronic System

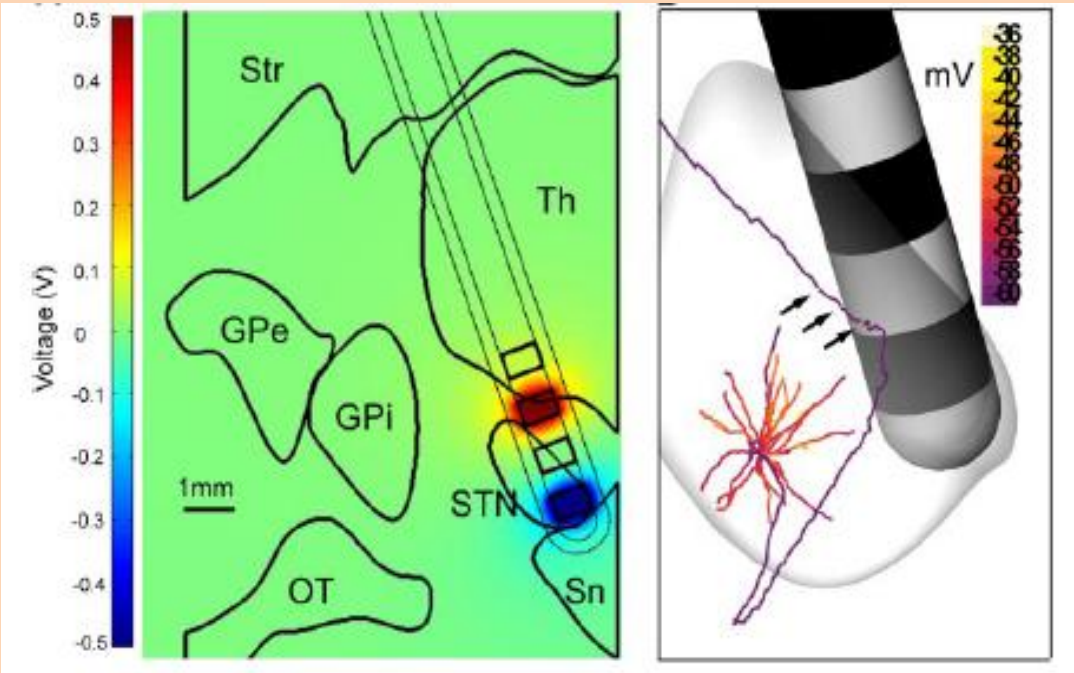
Deep Brain Stimulation has been useful for some patients in reducing the motor symptoms associated with Parkinson's Disease.

- 35,000: DBS – expanding clinical indications…
- 60,000: Cochlear Prosthetics
- 150,000: Urinary incontinence & spinal cord stimulation for pain

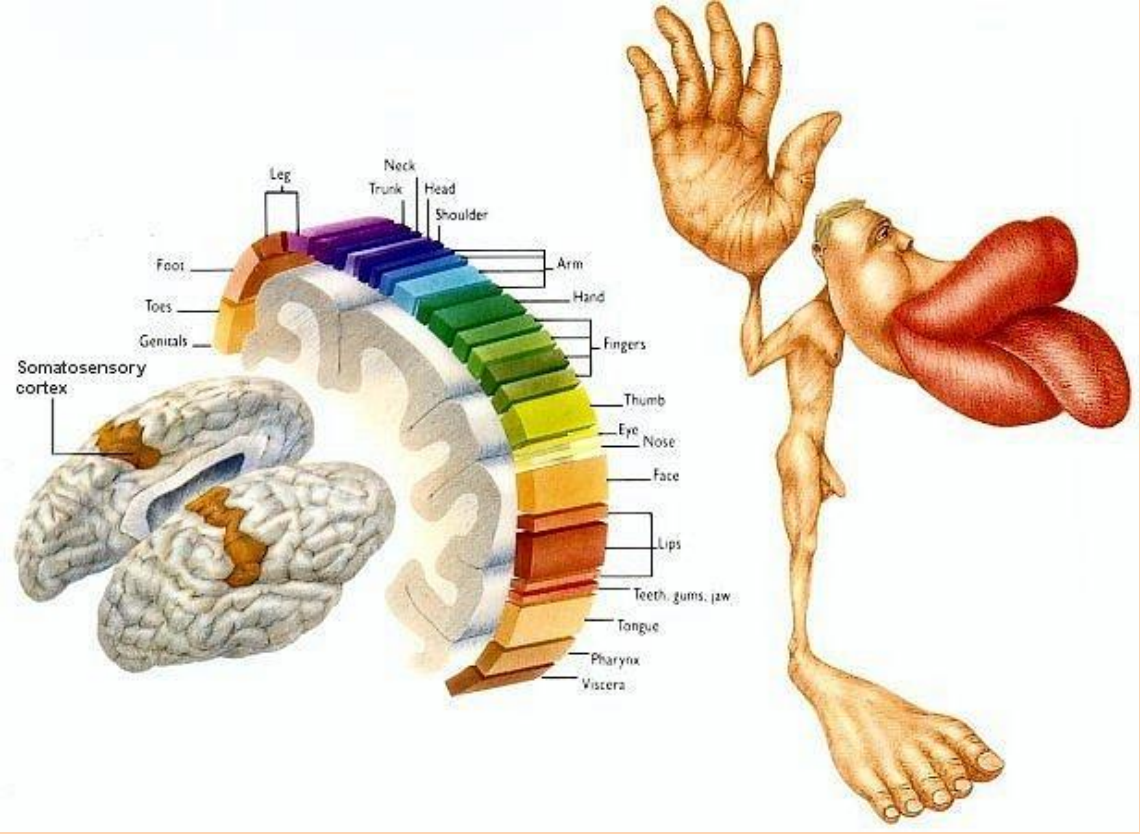
How does DBS work?

Miocinovic, et al., J. Neurophys., 2006.



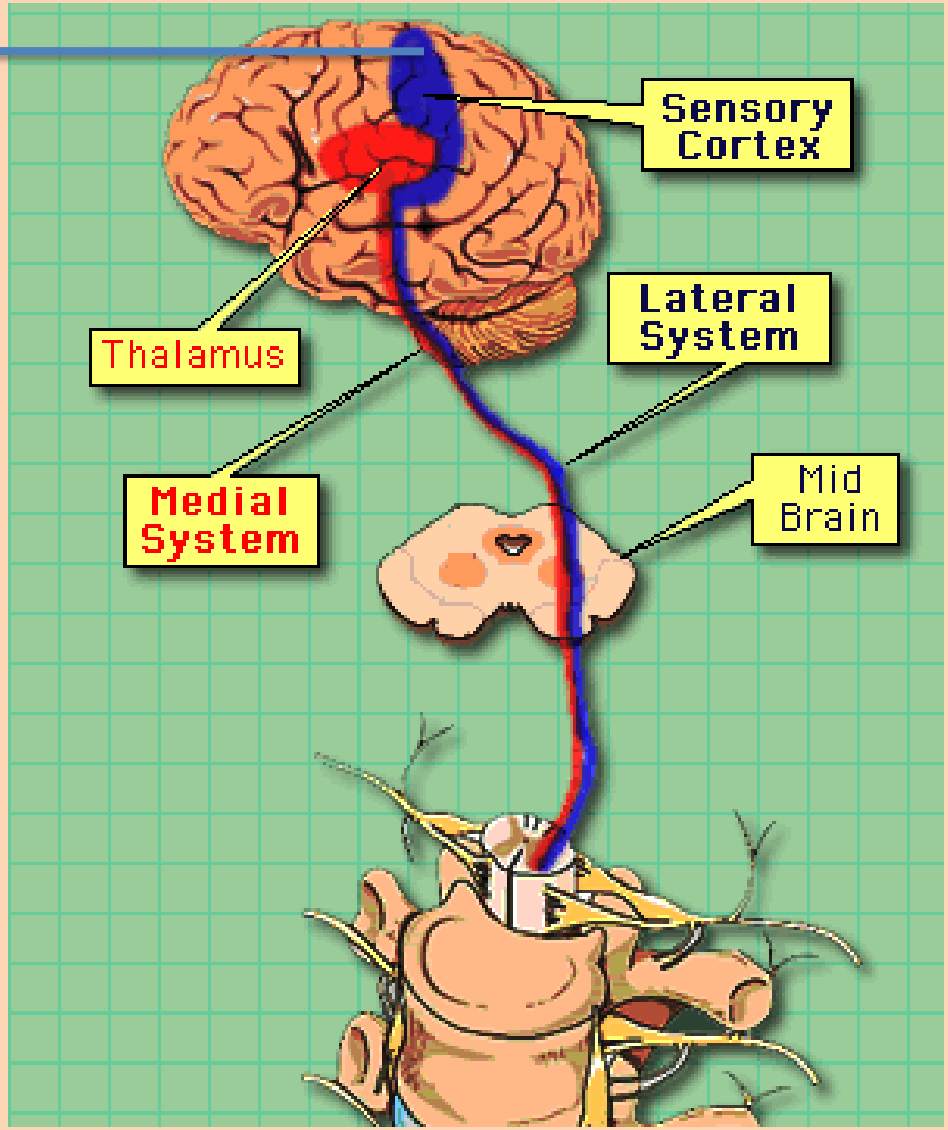


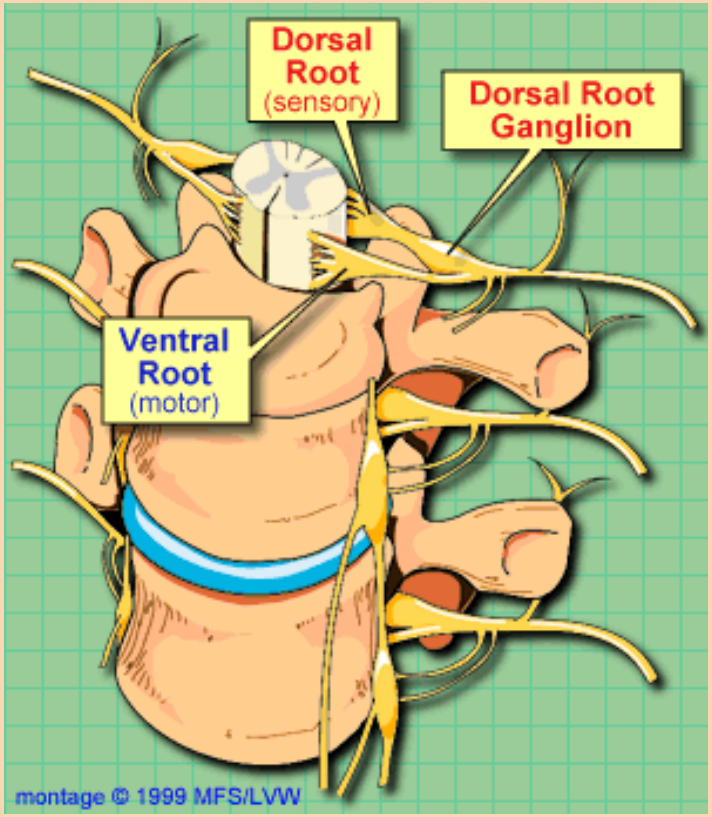
- DBS inhibits neurons in the STN via activation of presynaptic terminals while activating STN down stream fibers directly.
- DBS can activate GPi fibers directly in some cases, which may contribute to the therapeutic effect.
- Need a model that captures dynamics of networks – and stimuli


Leg
Neck
Trunk
Head
Shoulder
Foot
Arm
Toes
Hand
Genitals
Fingers
Somatosensory cortex
Thumb
Eye
Nose
Face
Lips
Teeth, gums, jaw
Tongue
Pharynx
Viscera

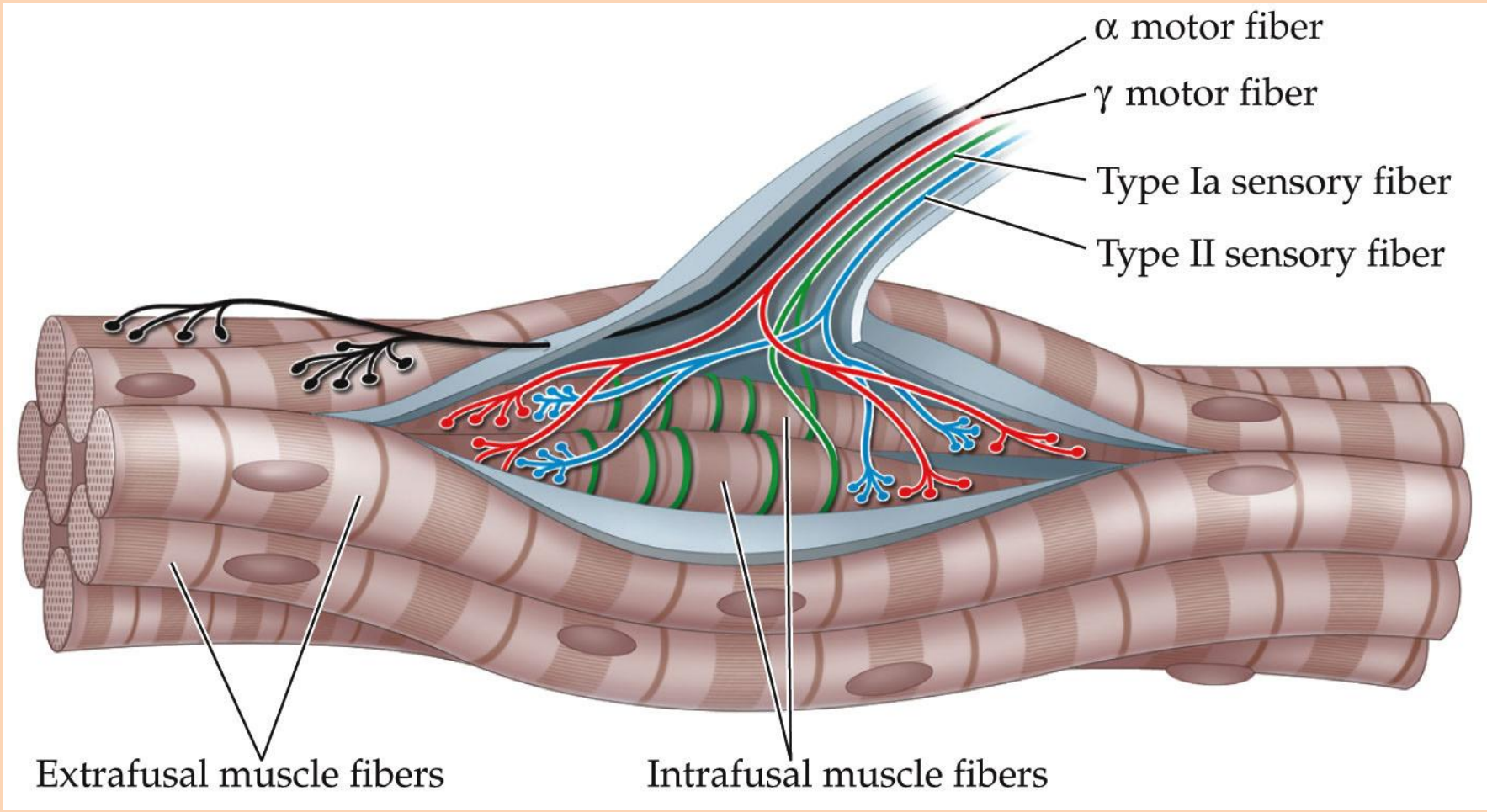
Sensory humumculus

SENSORY PATHWAYS FOR THE SENSE OF BODY IN SPACE

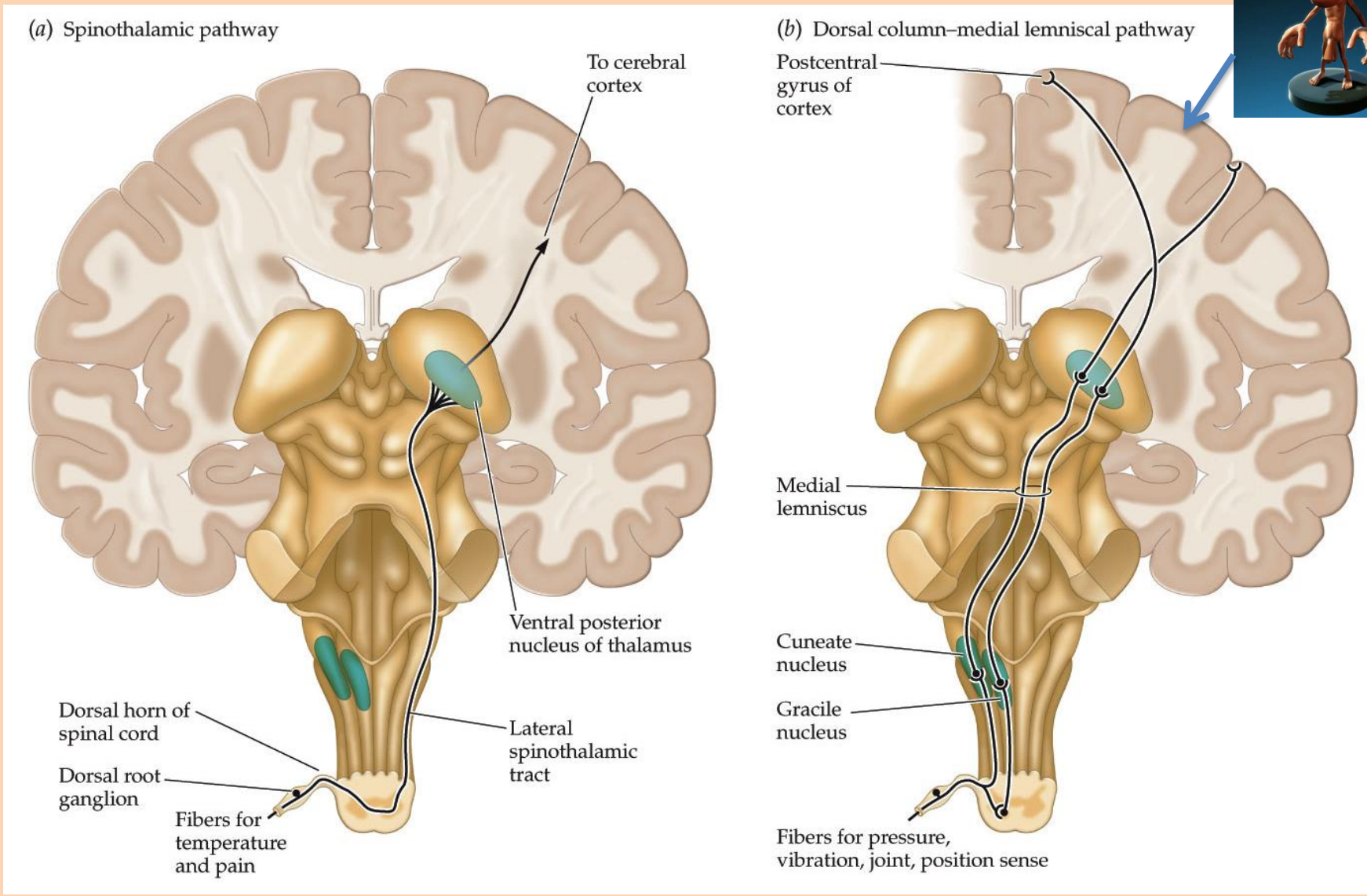




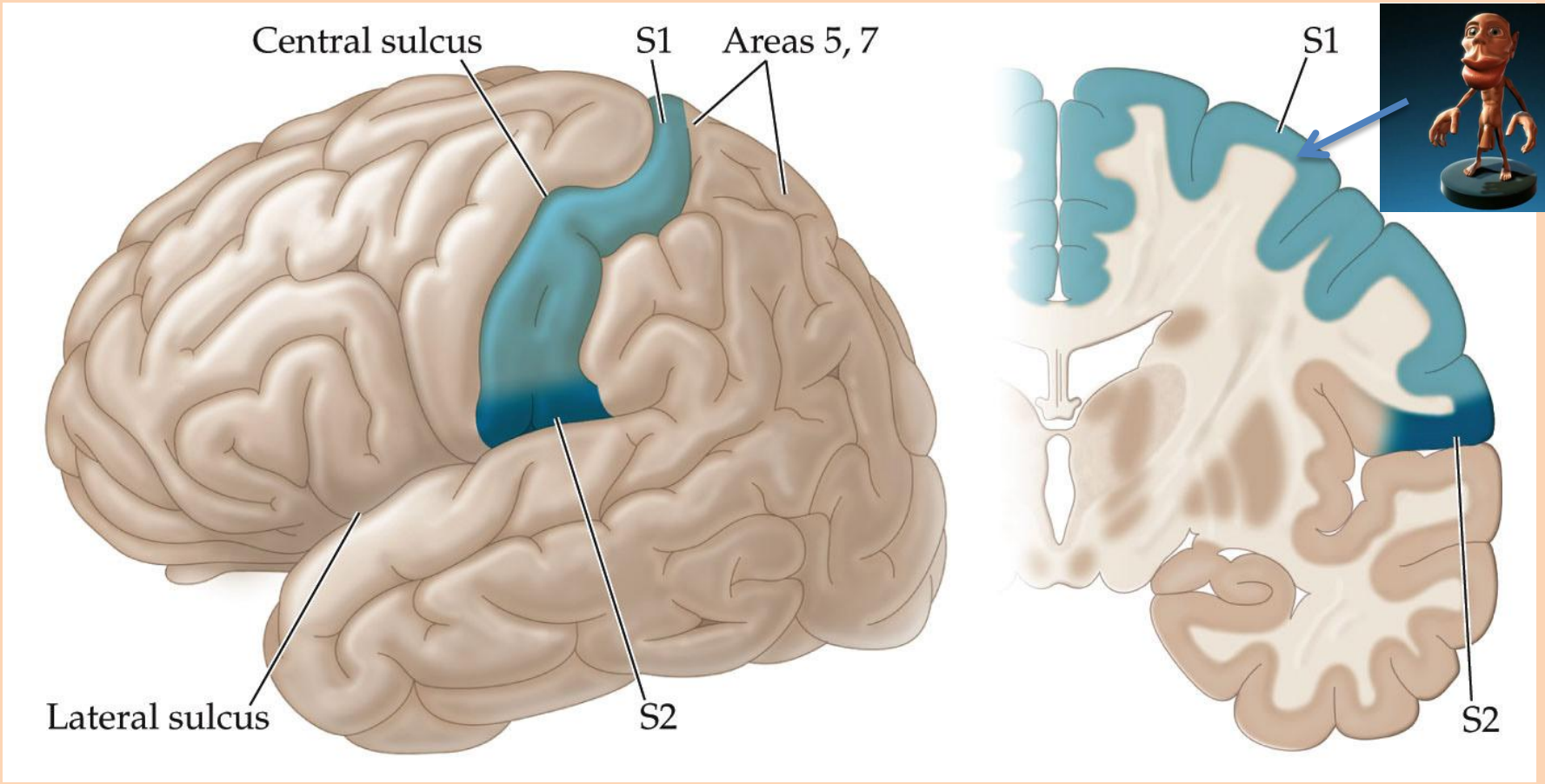
MUSCLE SPINDLE: SEPARATE FIBERS FOR MOTOR AND SENSORY AFFERENT INFORMATION



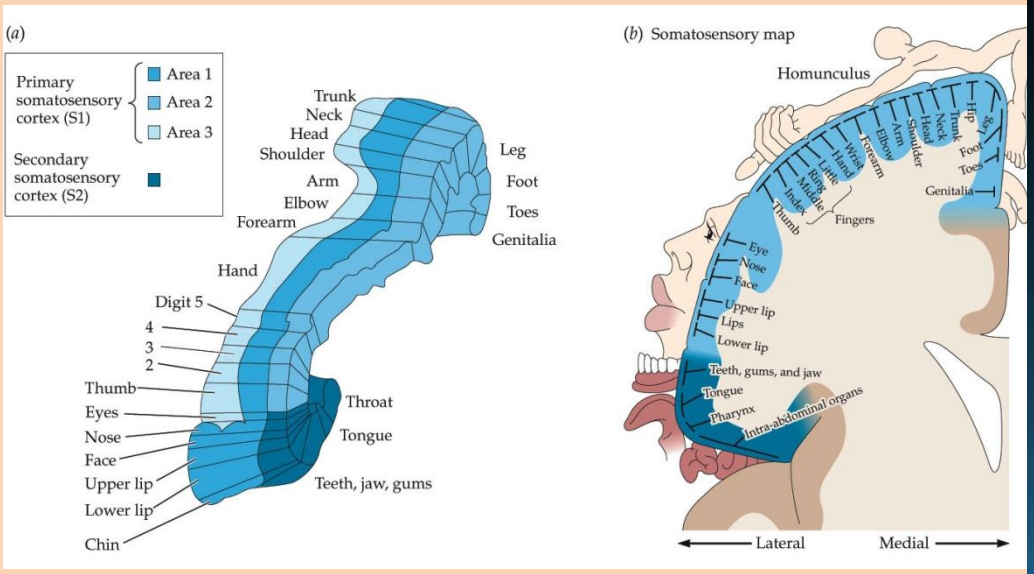
SENSORY INFO CAN TRAVEL EVEN 2METERS FROM FOOT TO CORTEX

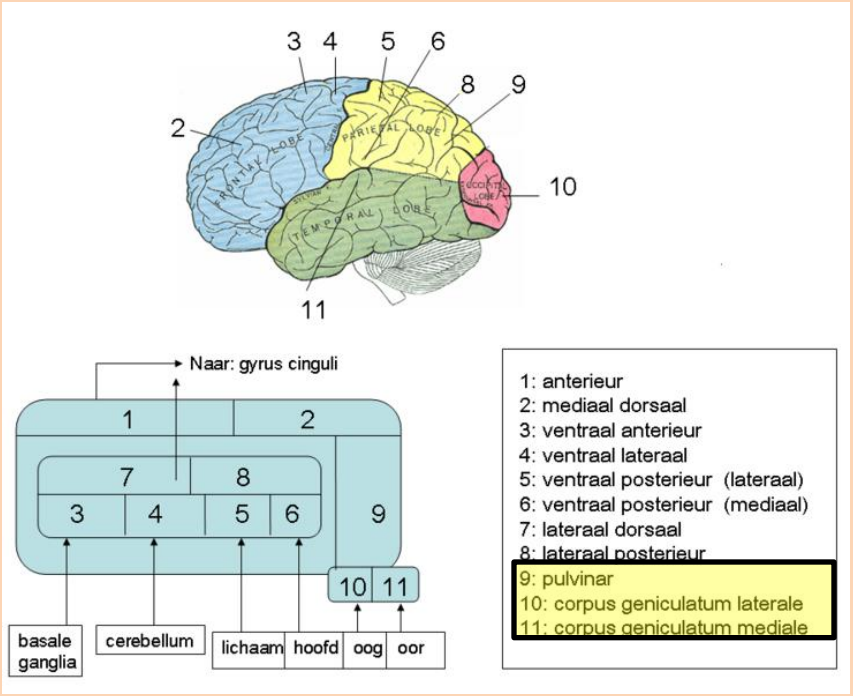


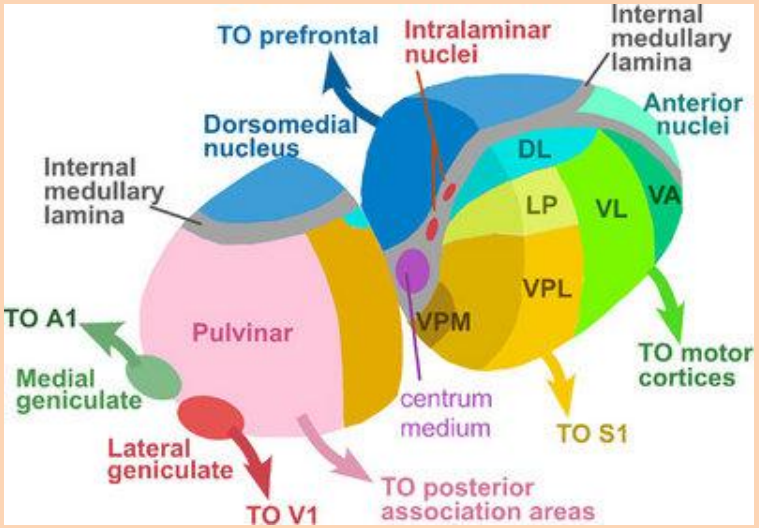
Primary somatosensory receiving areas in the brain



The sensory homunculus







Afferent and Efferent information in the periphery

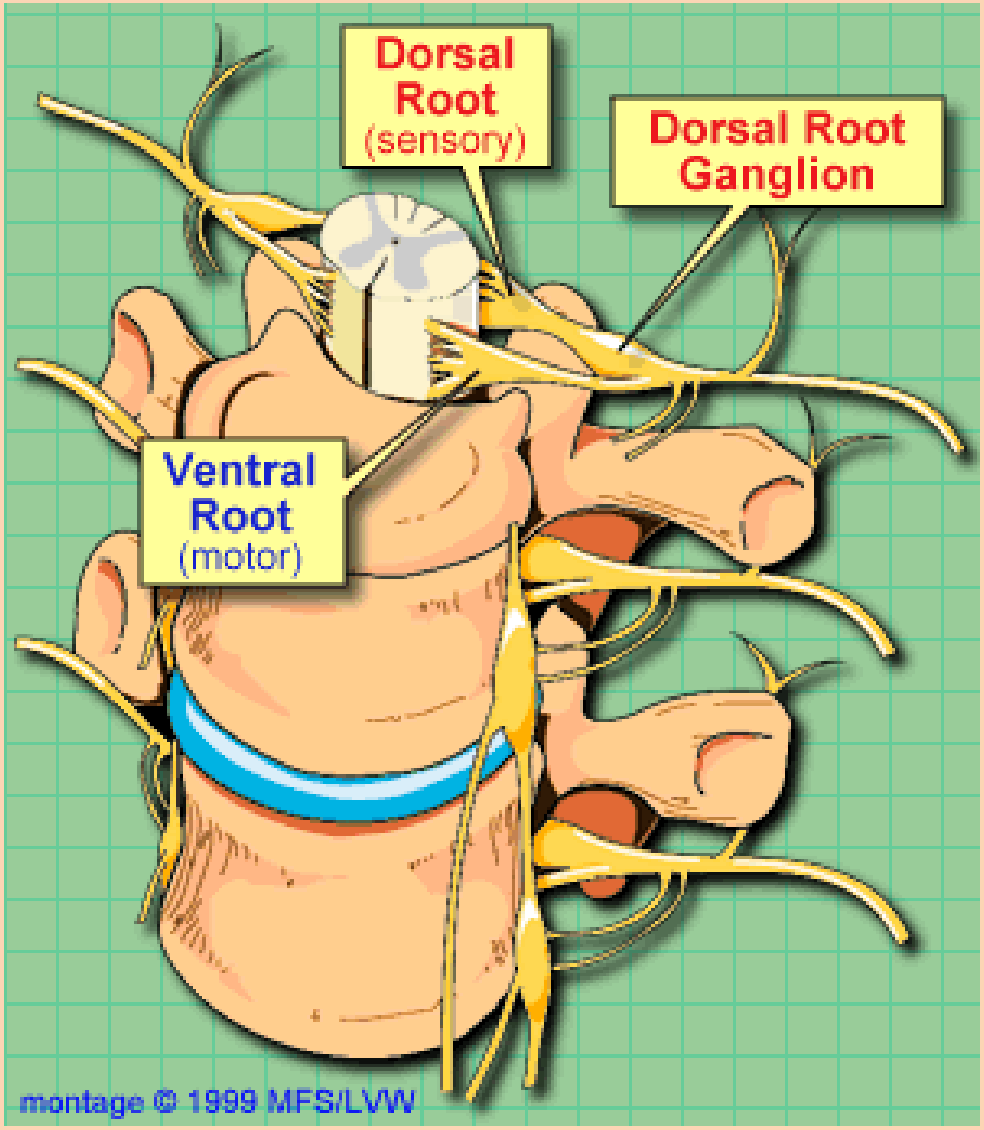
Pain

Temperature

Touch

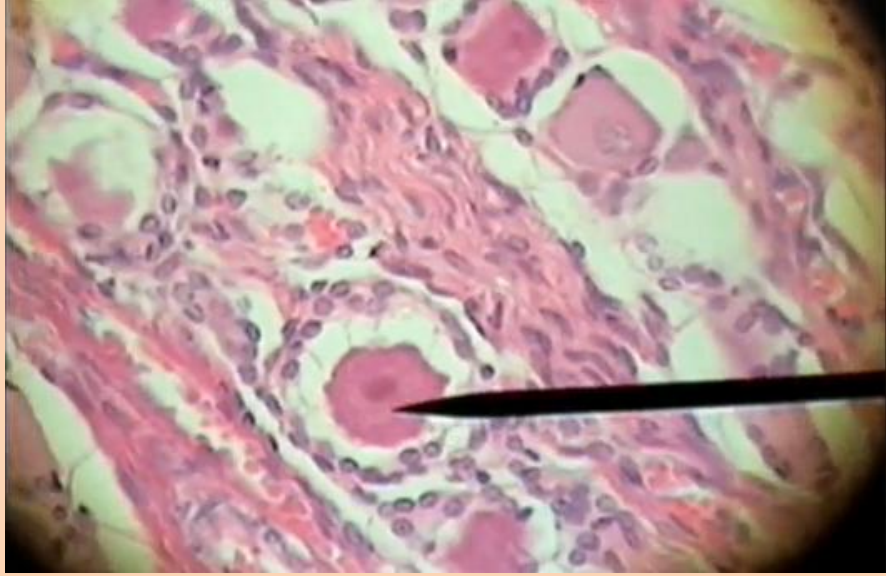
(Position and Movement)

SEPARATE SENSORY AND MOTOR PATHWAYS

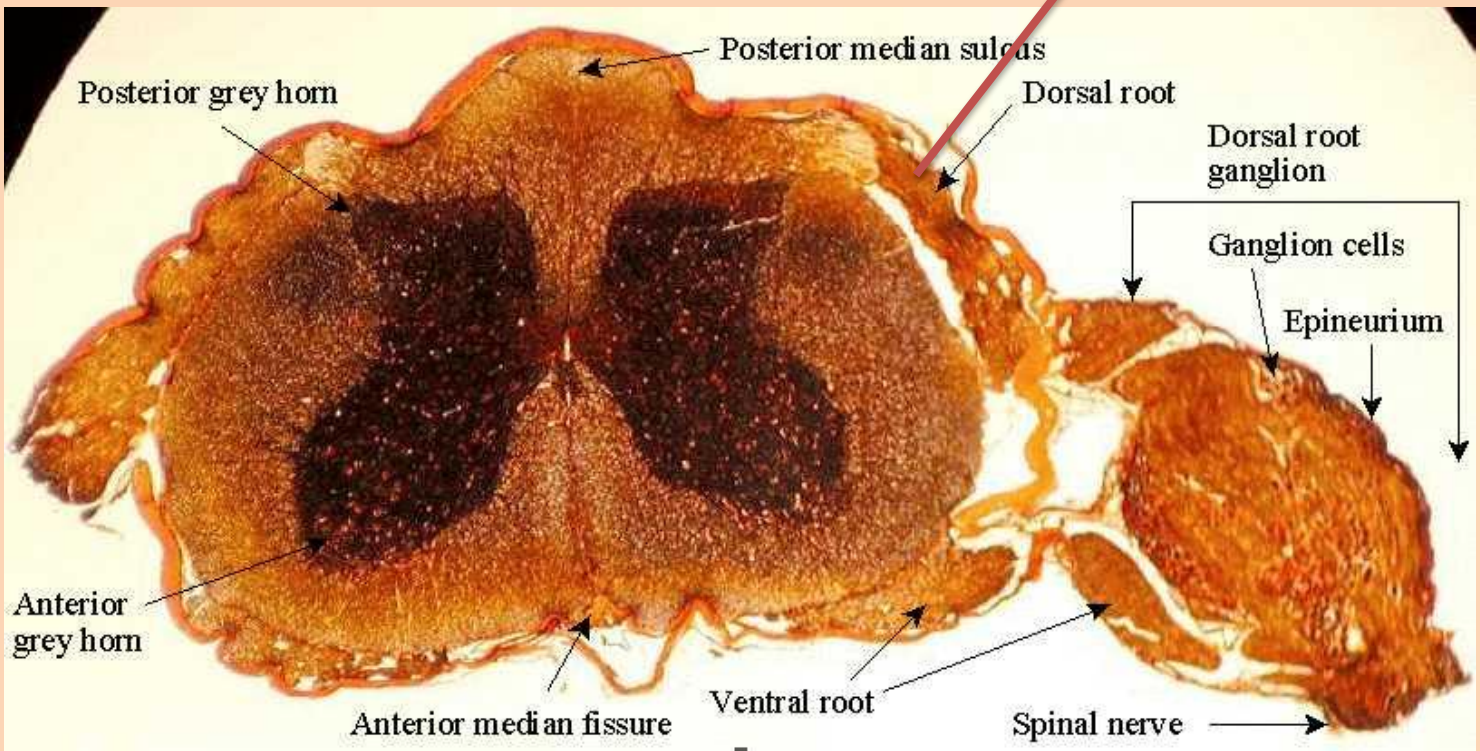


Jonathan Coles' DISCOVERY

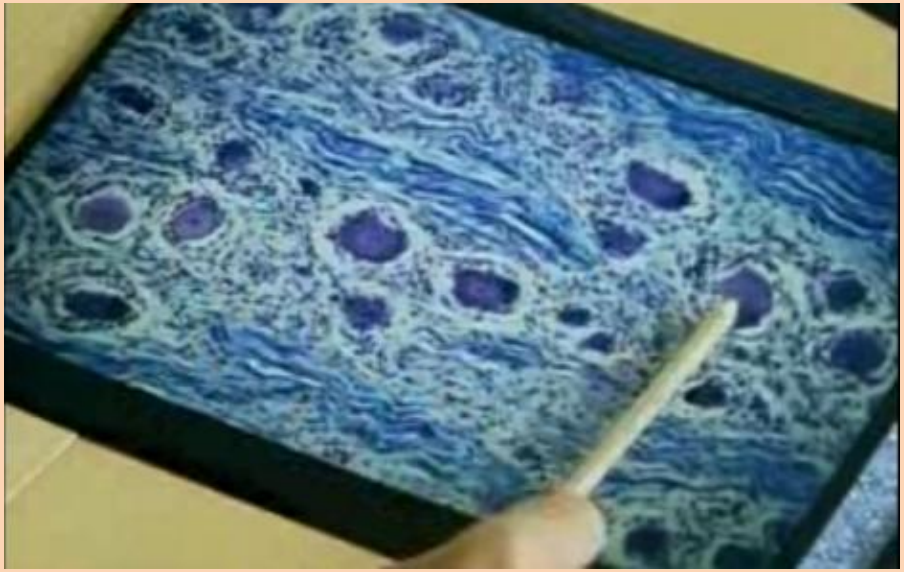
DORSAL ROOT GANGLION CELLS
PERIPHERAL NERVOUS SYSTEM
AFFERENT FIBERS

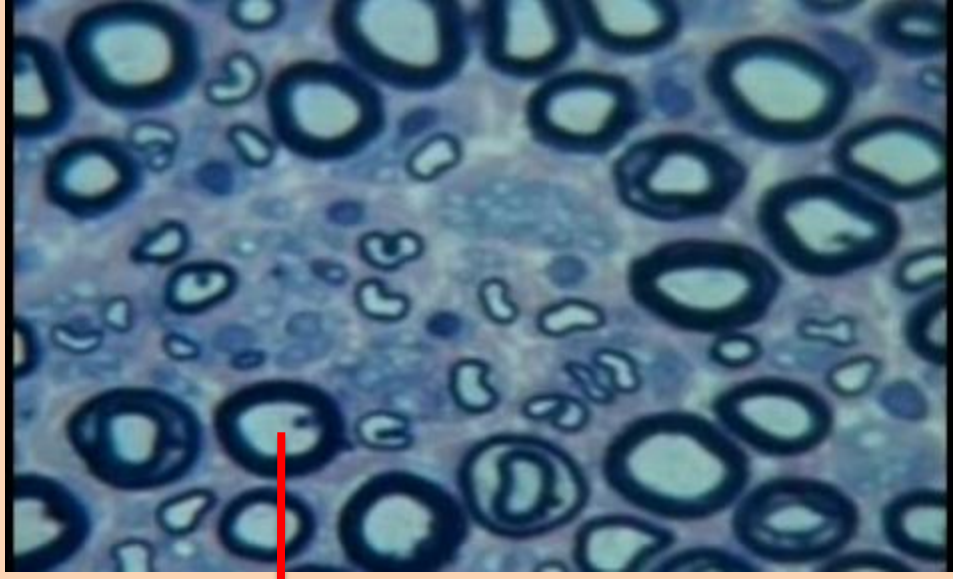


Cell Body

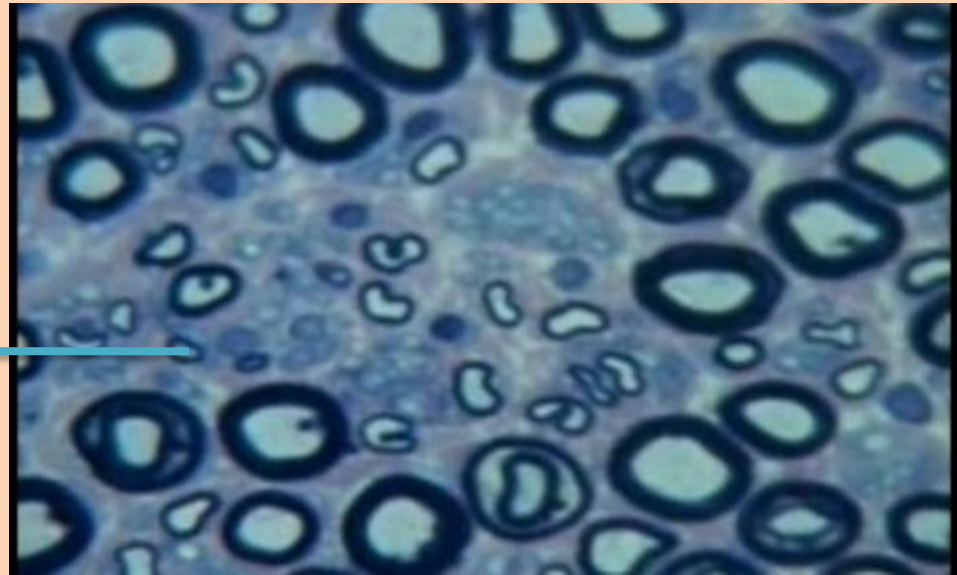


PERIPHERAL AFFERENT SENSORY FIBERS



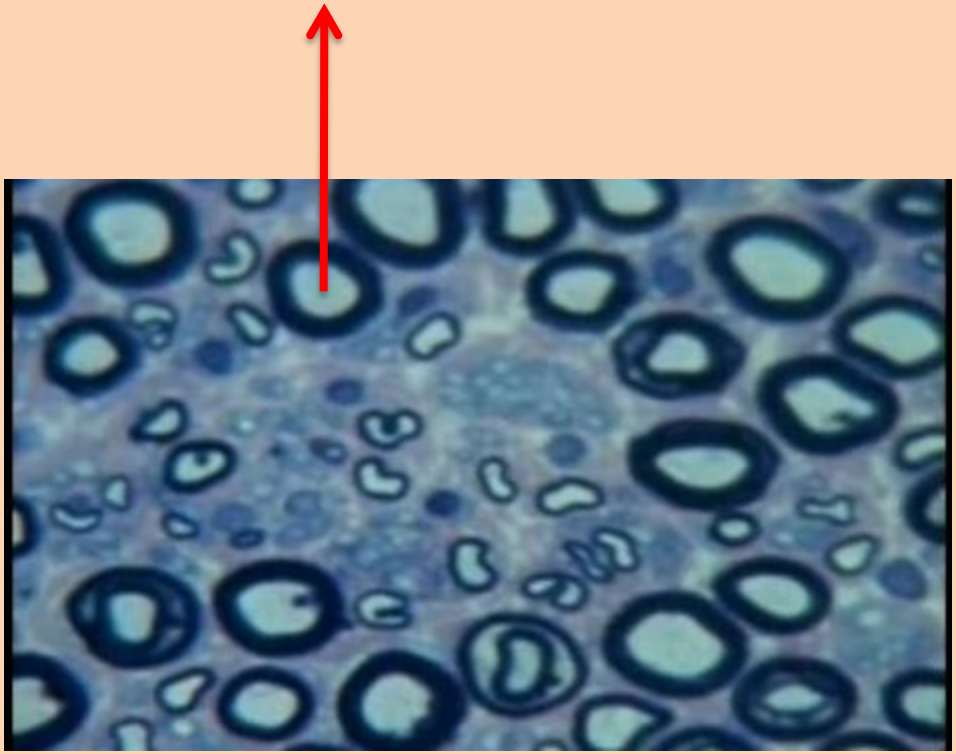


LARGE ONES CONVEY, sense of BODY POSITION TOUCH, MOVEMENT SENSE, MUSCLE SENSE



SMALL ONES CONVEY TEMPERATURE, MUSCLE FATIGUE, SOME PAIN

LARGE FIBERS CONVEY THE SENSE OF BODY POSITION AND TOUCH



CONTRIBUTE TO THE SENSE OF PROPRIOCEPTION

THESE WERE THE FIBERS THAT GOT DESTROYED IN

IAN WATREMAN'S CASE BY A VIRAL INFECTION

AN EXAMPLE OF AN INSTRUMENTAL ACT AFTER DEAFFERENTATION

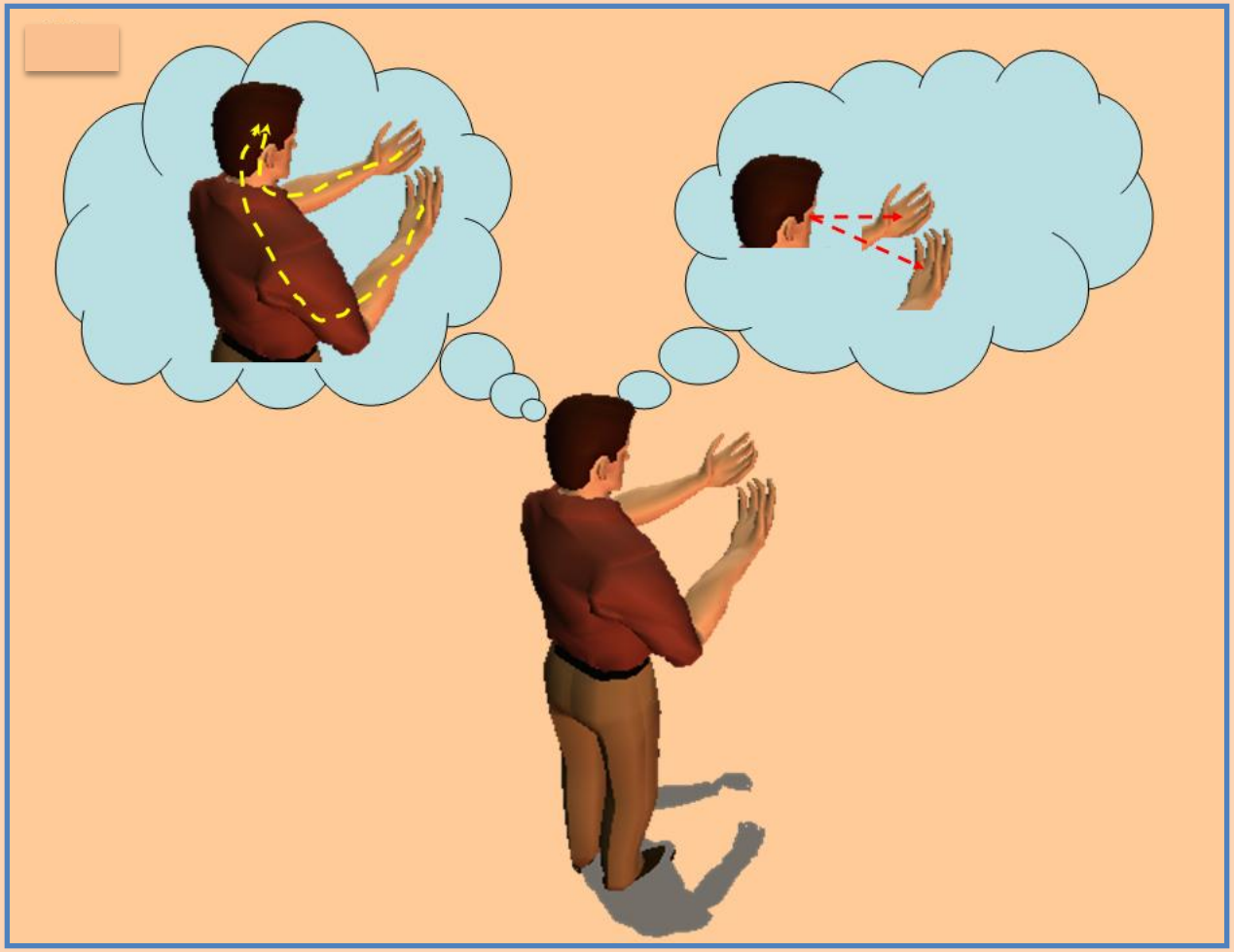
HE HAS TO CAREFULLY WATCH HIS HANDS AND THE OBJECT TO GRASP IT

THERE IS NO AUTOMATICITY LEFT

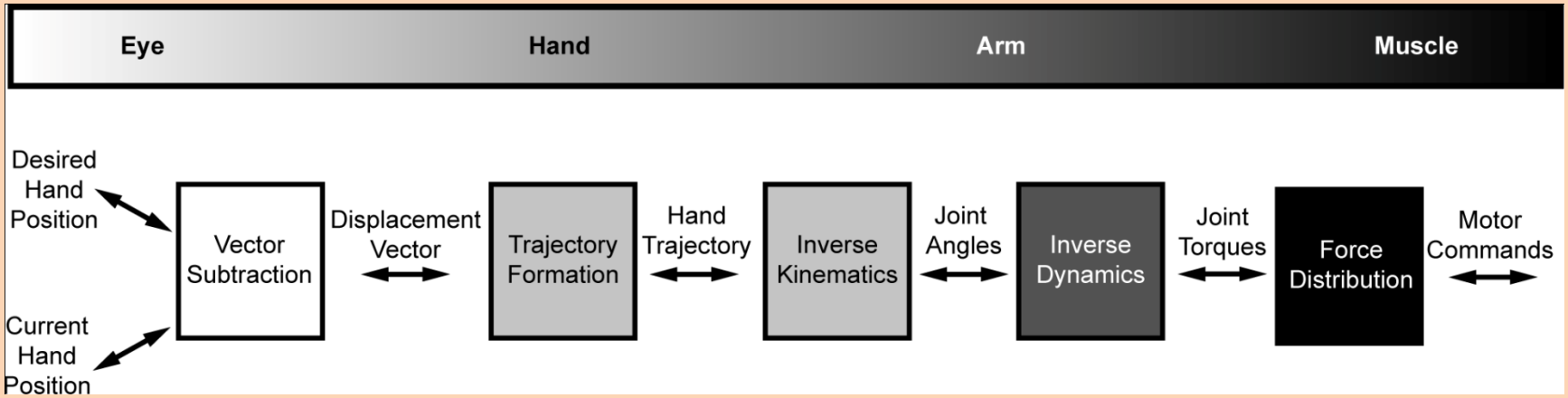
Perceive Movement Visually

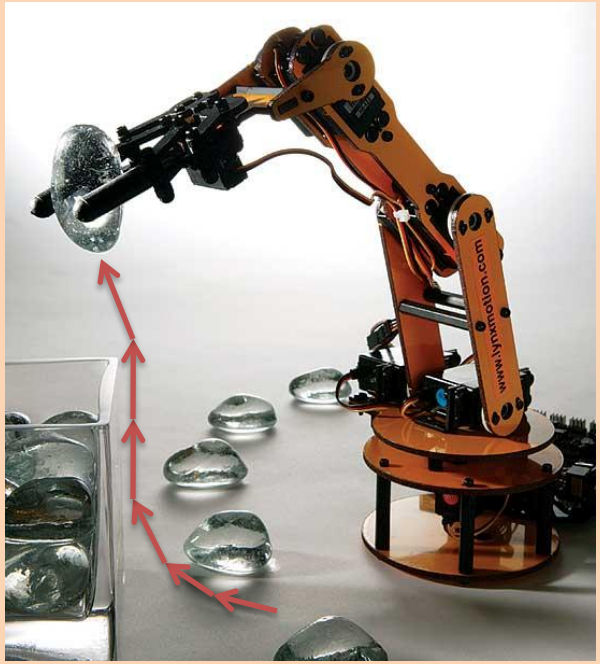
vs.

Perceive it kinesthetically

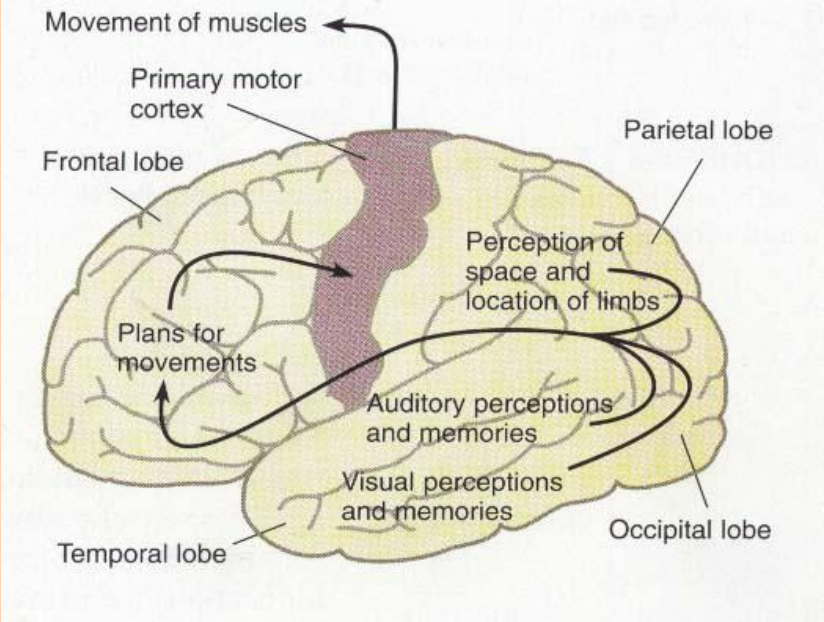


How do we go from a visual representation of the goal to a movement that accomplishes that goal?

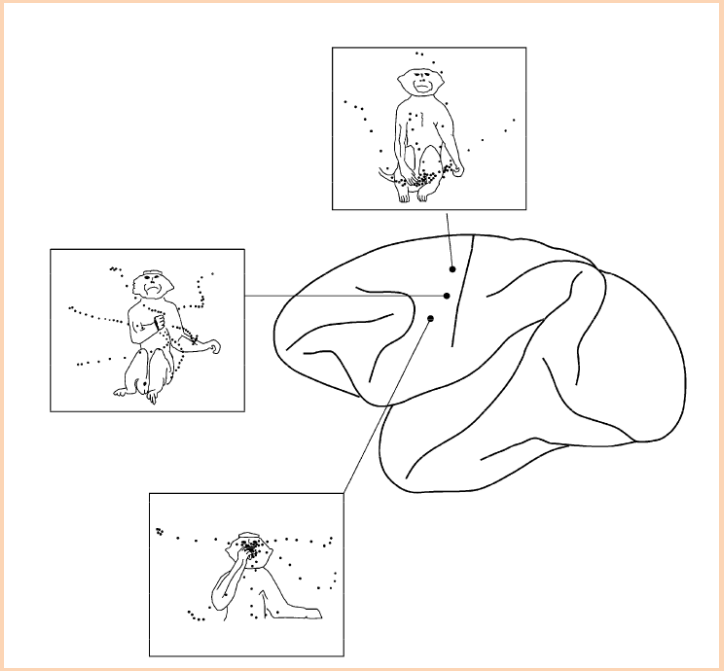


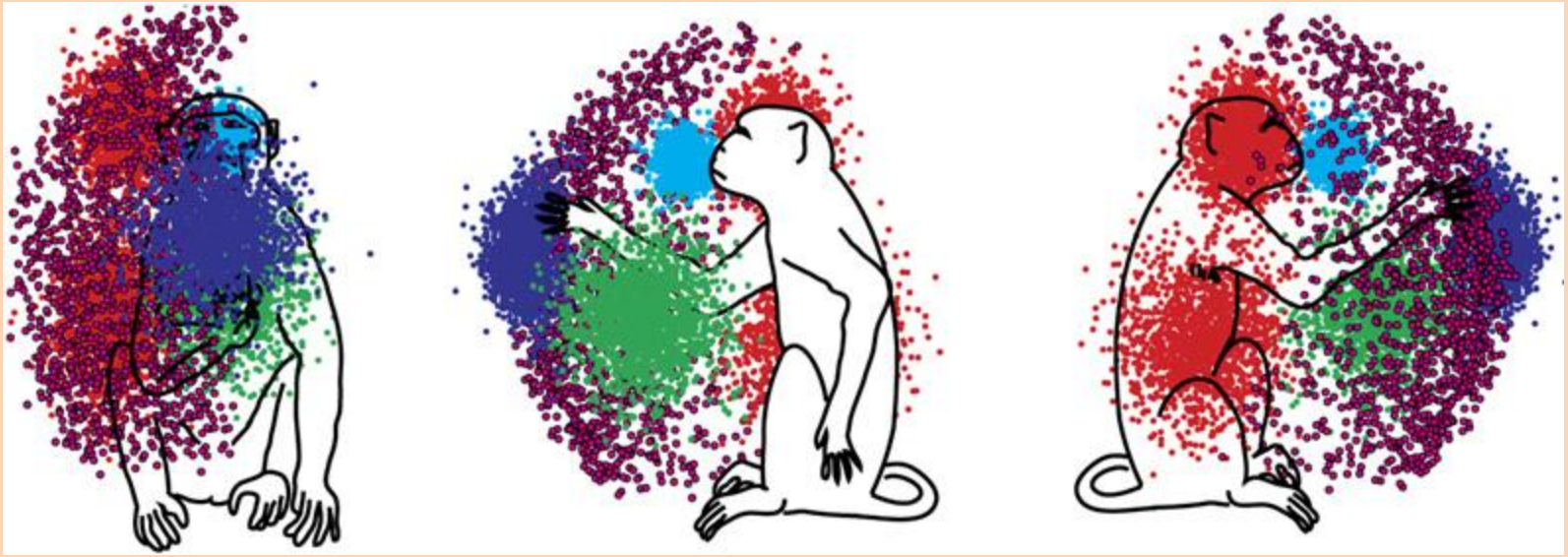


What is the “optimal” source of control signals?

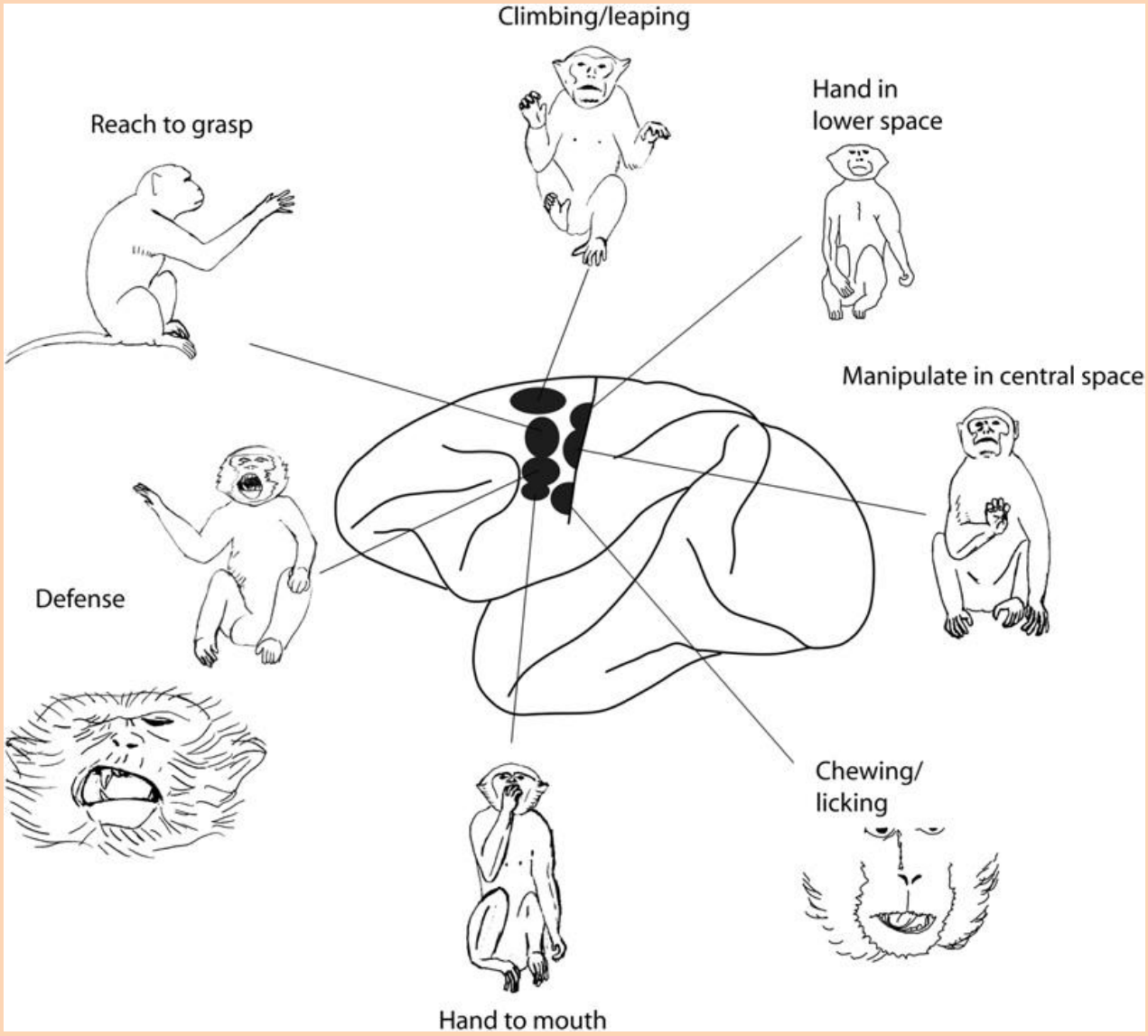


Graziano's Work





Graziano & Aflalo, Neuron 2007


Climbing/leaping
Reach to grasp
Hand in
lower space
Manipulate in central space
Defense
Chewing/
licking
Hand to mouth

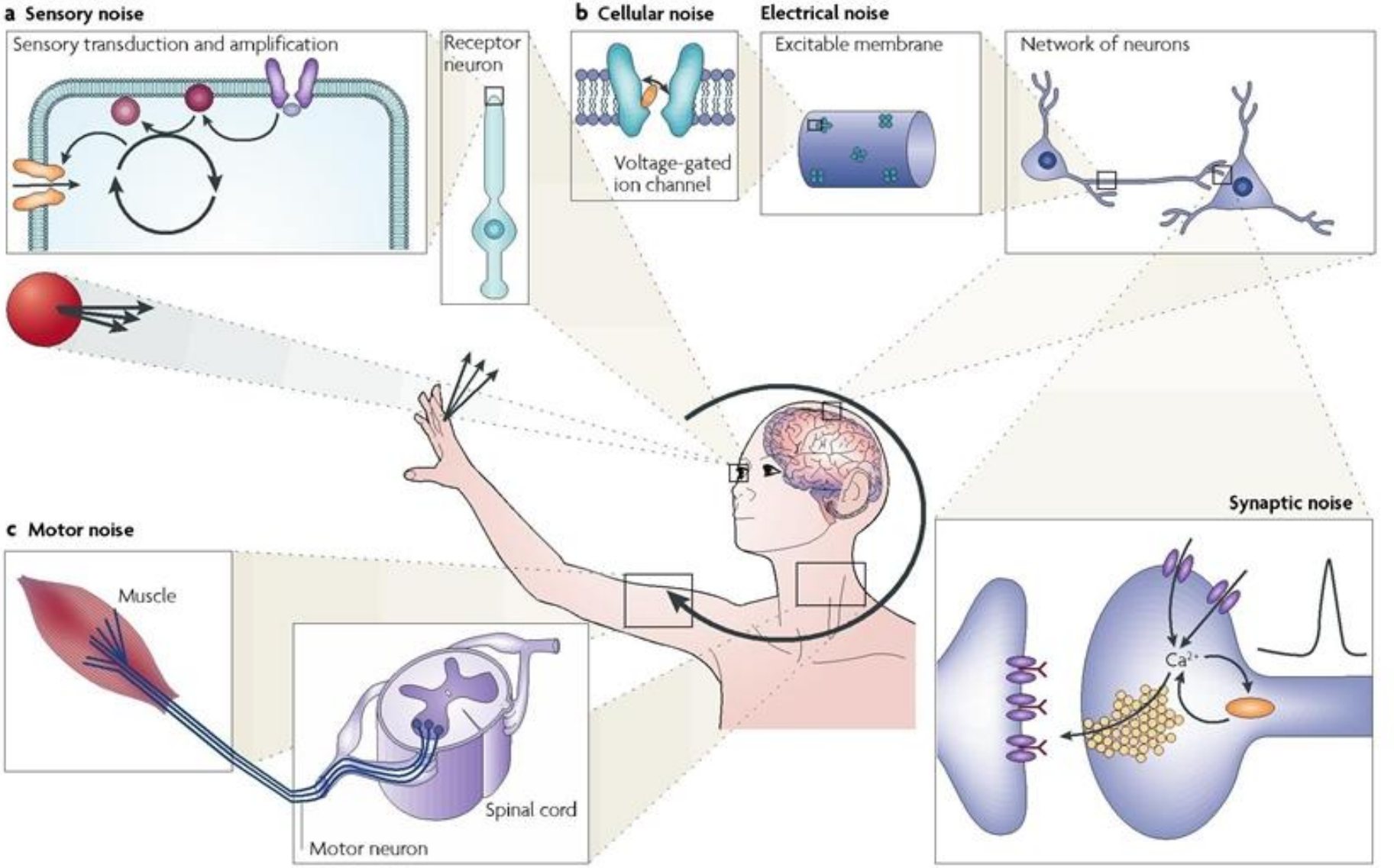
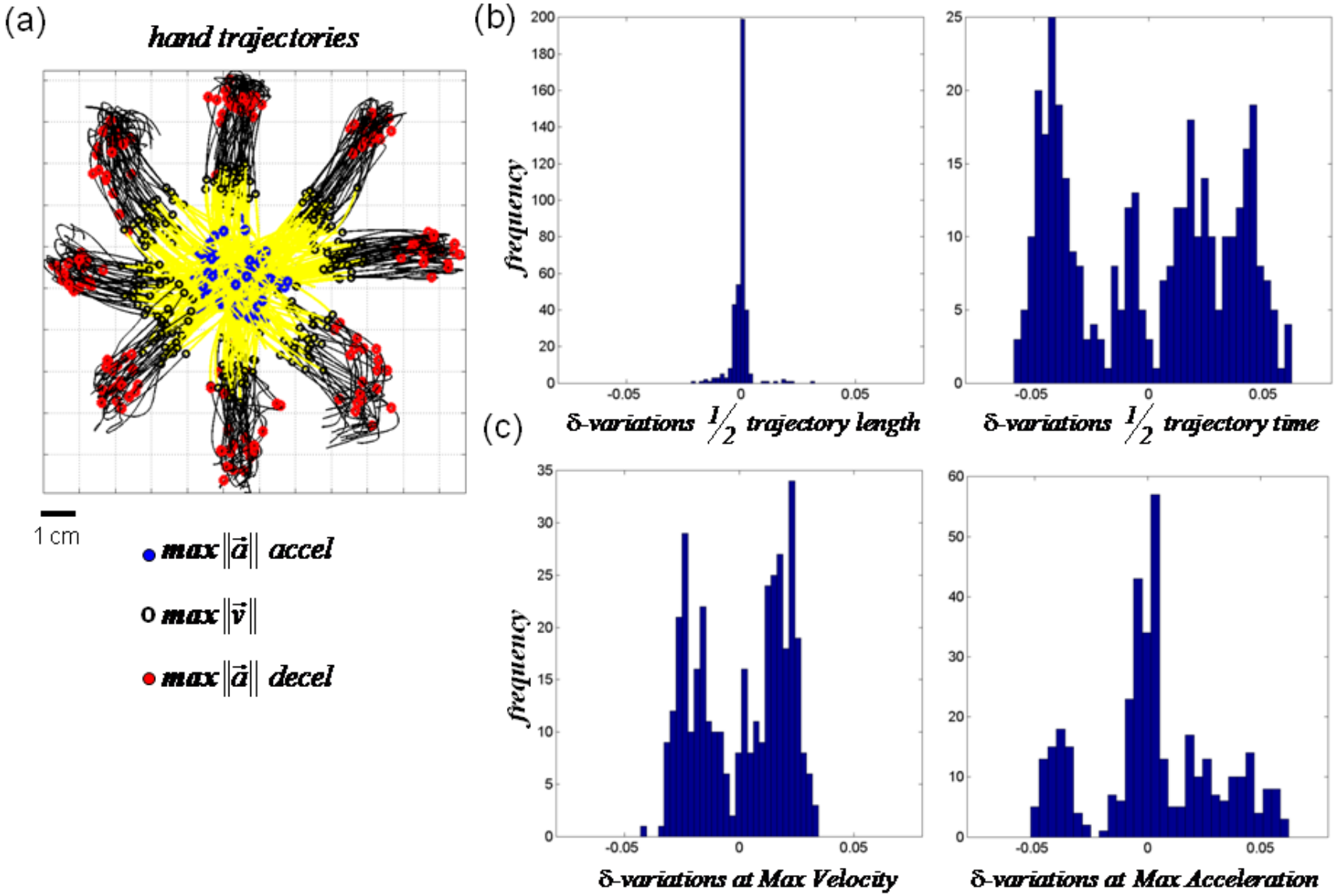
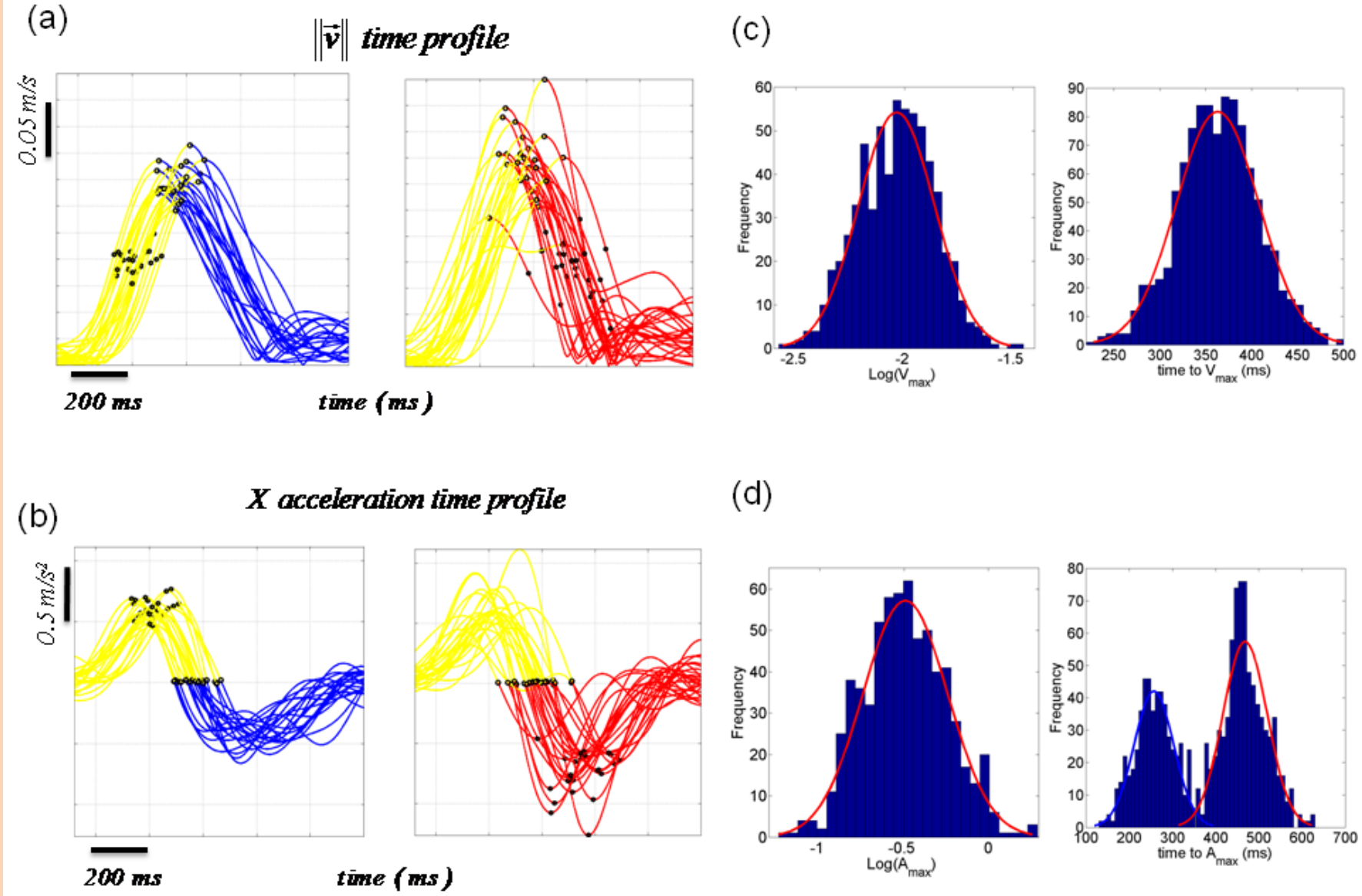


Figure 1 | **Overview of the behavioural loop and the stages at which noise is present in the nervous system.** **a** | Sources of sensory noise include the transduction of signals. This is exemplified here by a photoreceptor and its signal-amplification cascade. **b** | Sources of cellular noise include the ion channels of excitable membranes, synaptic transmission and network interactions (see BOX 2). **c** | Sources of motor noise include motor neurons and muscle. In the behavioural task shown (catching a ball), the nervous system has to act in the presence of noise in sensing, information processing and movement.

Hand Trajectories and their statistics

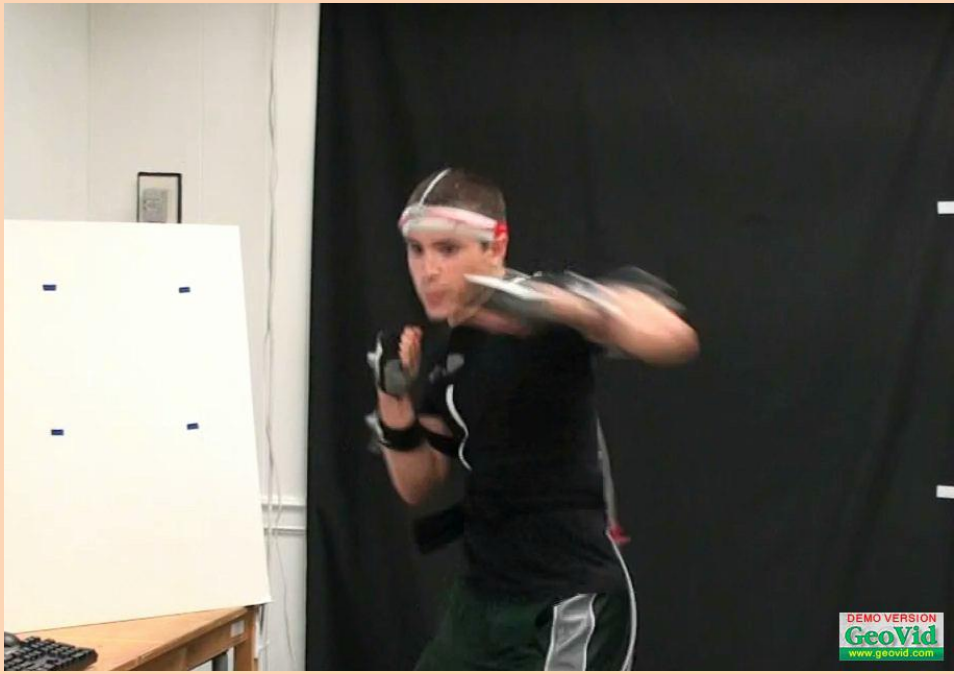


Multiple temporal coverings along the stable path
Unexpected Statistical Properties –LogNormal Distributions



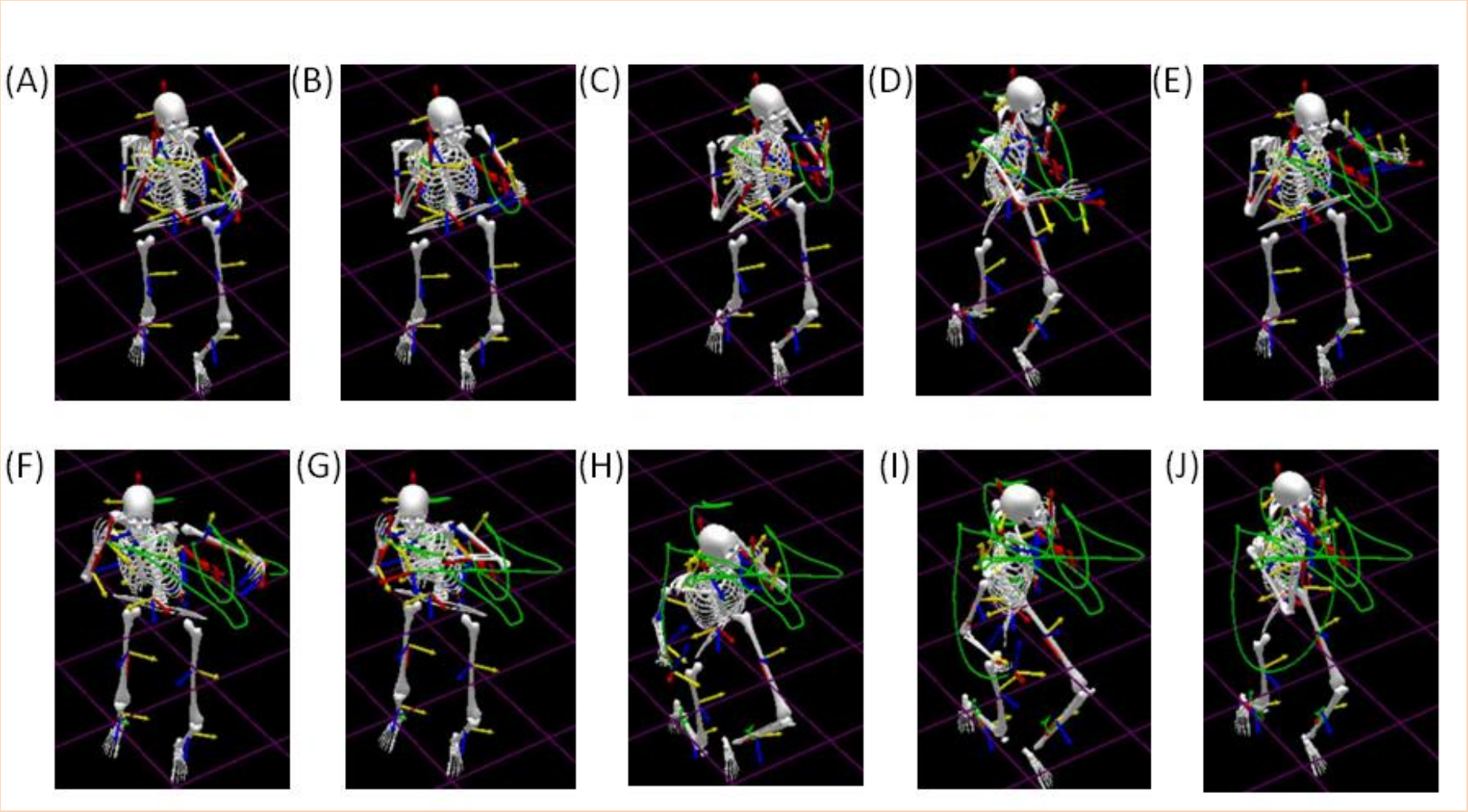
Complex Behaviors

Adaptation to loads

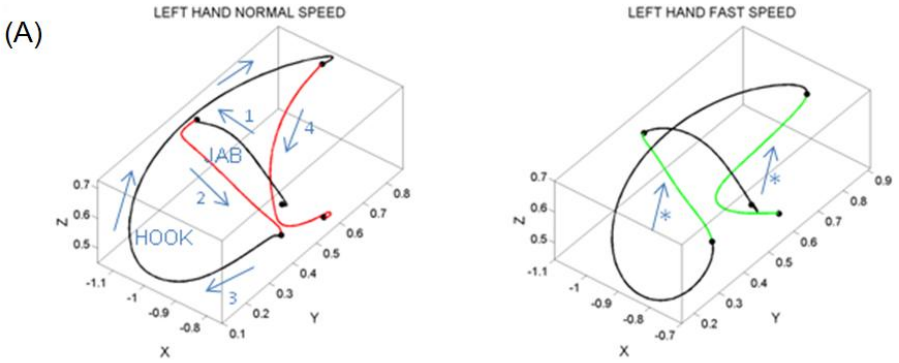


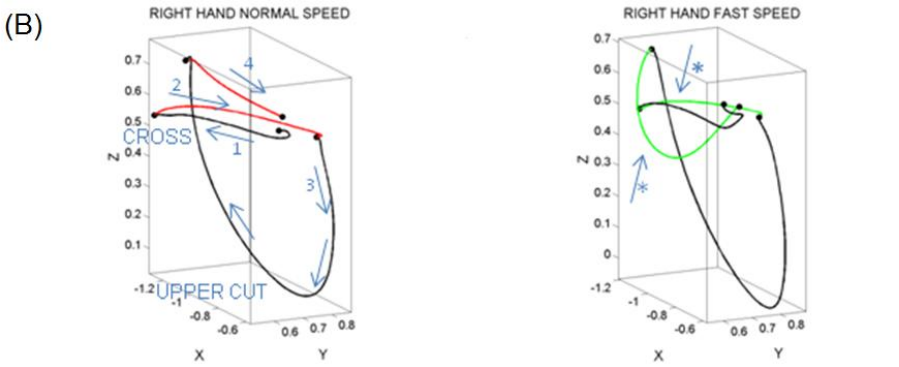
Complex Behaviors

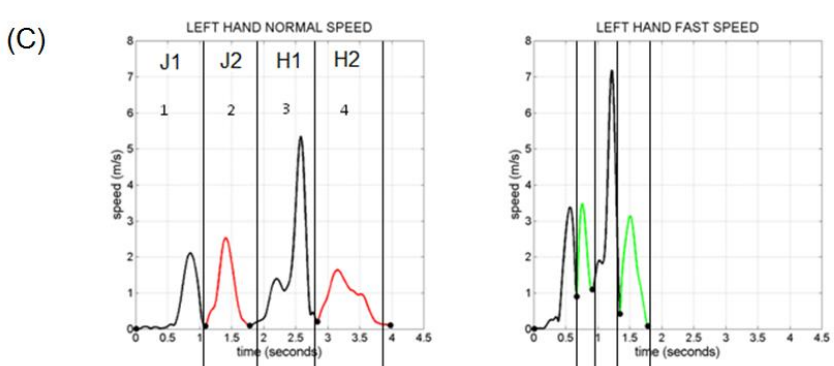
JAB – CROSS – HOOK – UPPER CUT

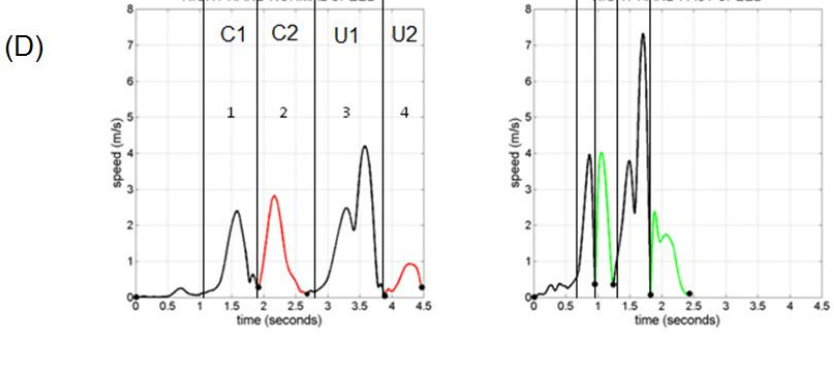


Staged vs Incidental movements

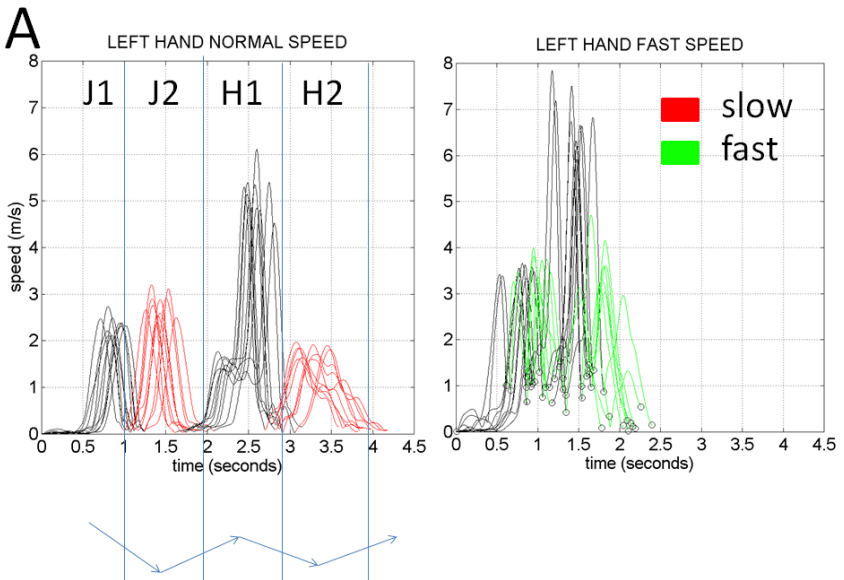


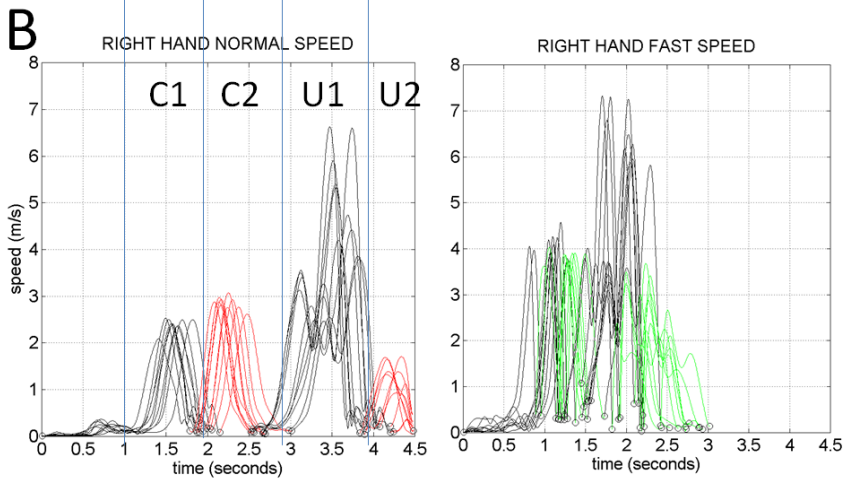


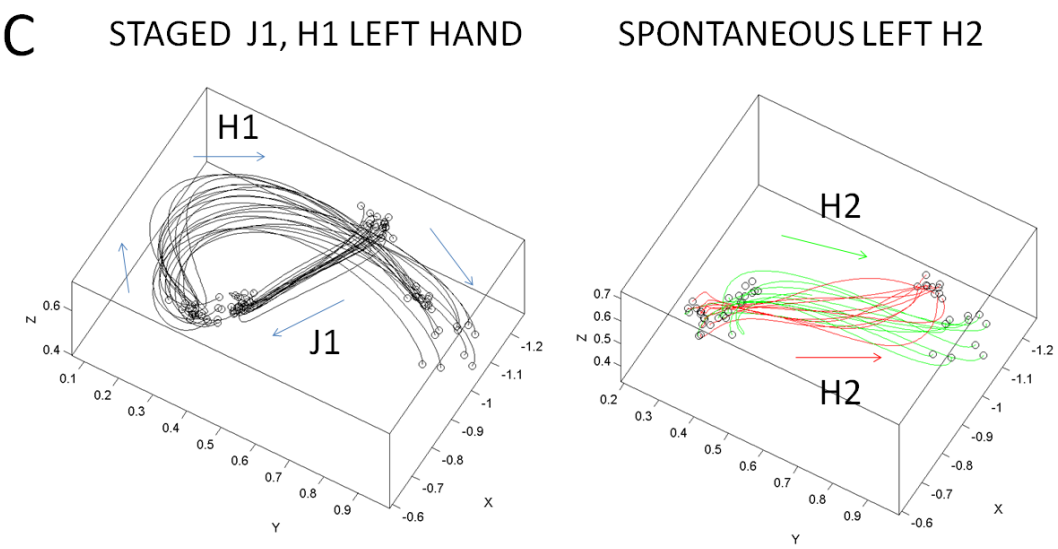


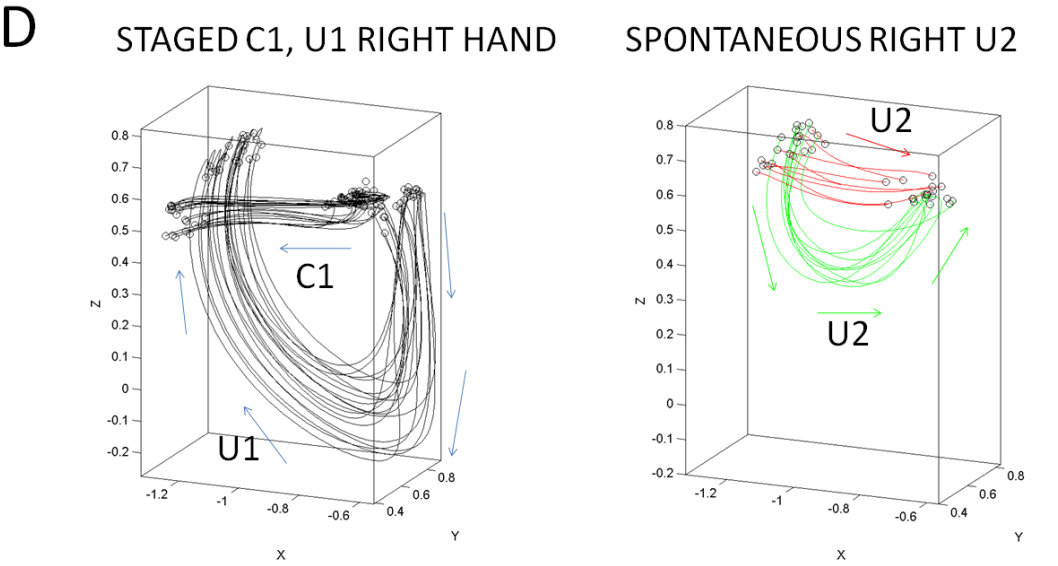


4 martial arts techniques decomposed into staged and incidental segments









The emergence of spontaneous, automated movements
“Not from seeing the movement, not from feeling the movement
But from imagining the movement”