第六讲

脑与认知科学

脑与认知加工：感觉运动

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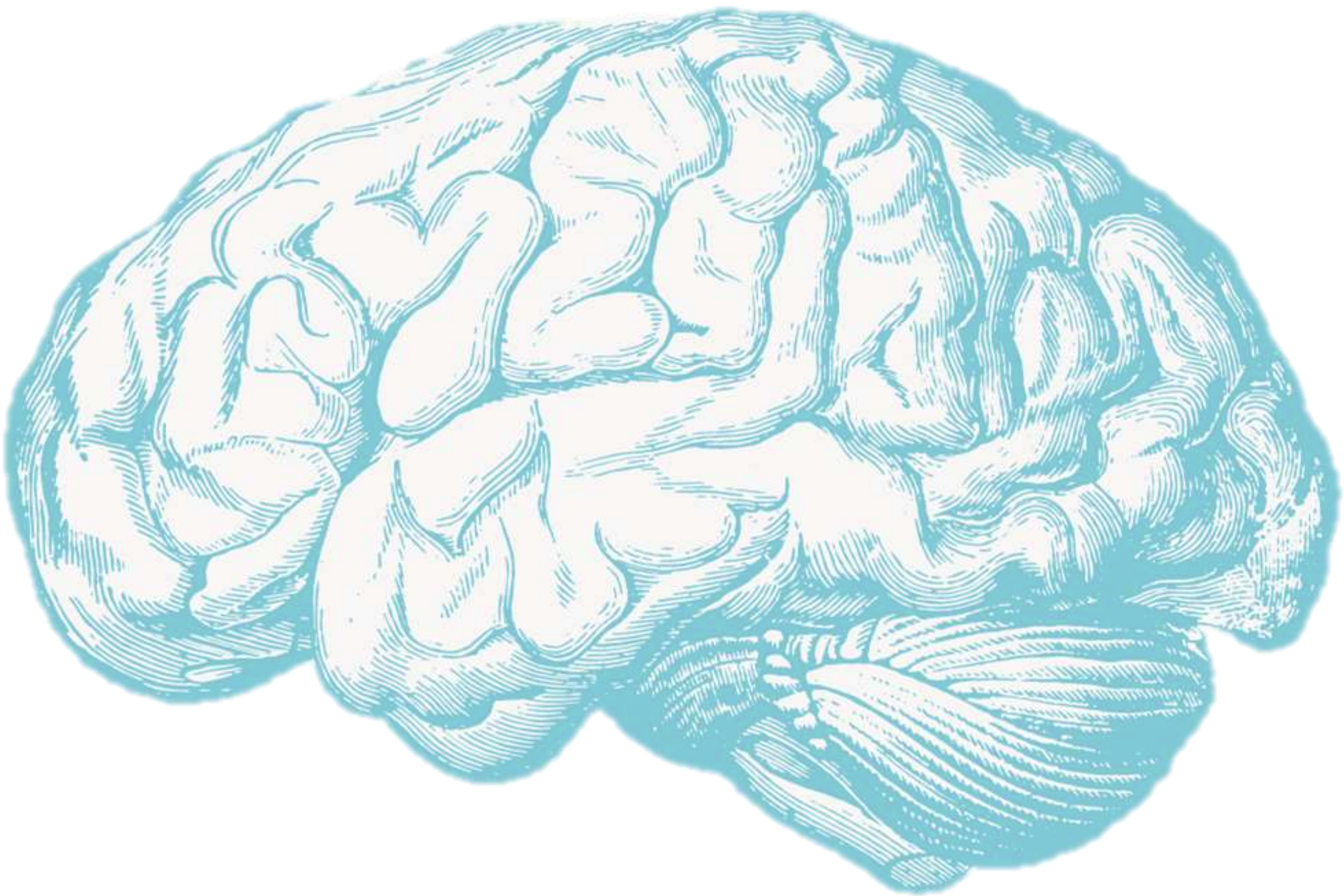

教师介绍

甄宗雷，男，北京师范大学心理学部教授，博士生导师，中科院自动化所计算机应用技术博士，长期在认知神经科学方向开展工作采用磁共振/脑磁图，神经编解码模型和人工智能等多种方法研究人脑视觉和运动的认知神经机制及其发展发育，并基于人脑认知神经新发现开发类脑计算模型。研究结果已发表在Nature Neuroscience, Nature Communications, PLoS Biology, eLife, The Journal of Neuroscience等领域高影响力期刊。

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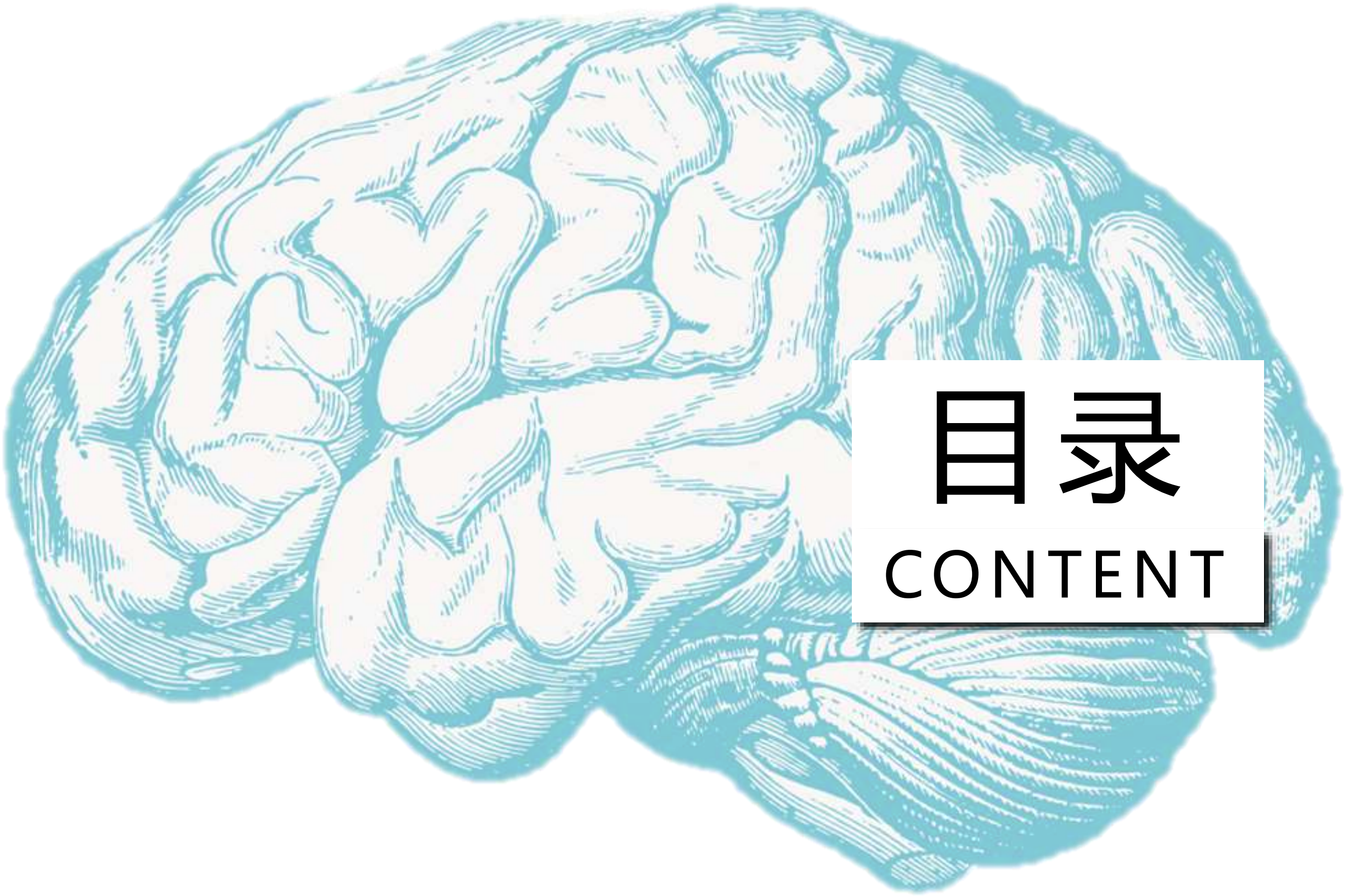

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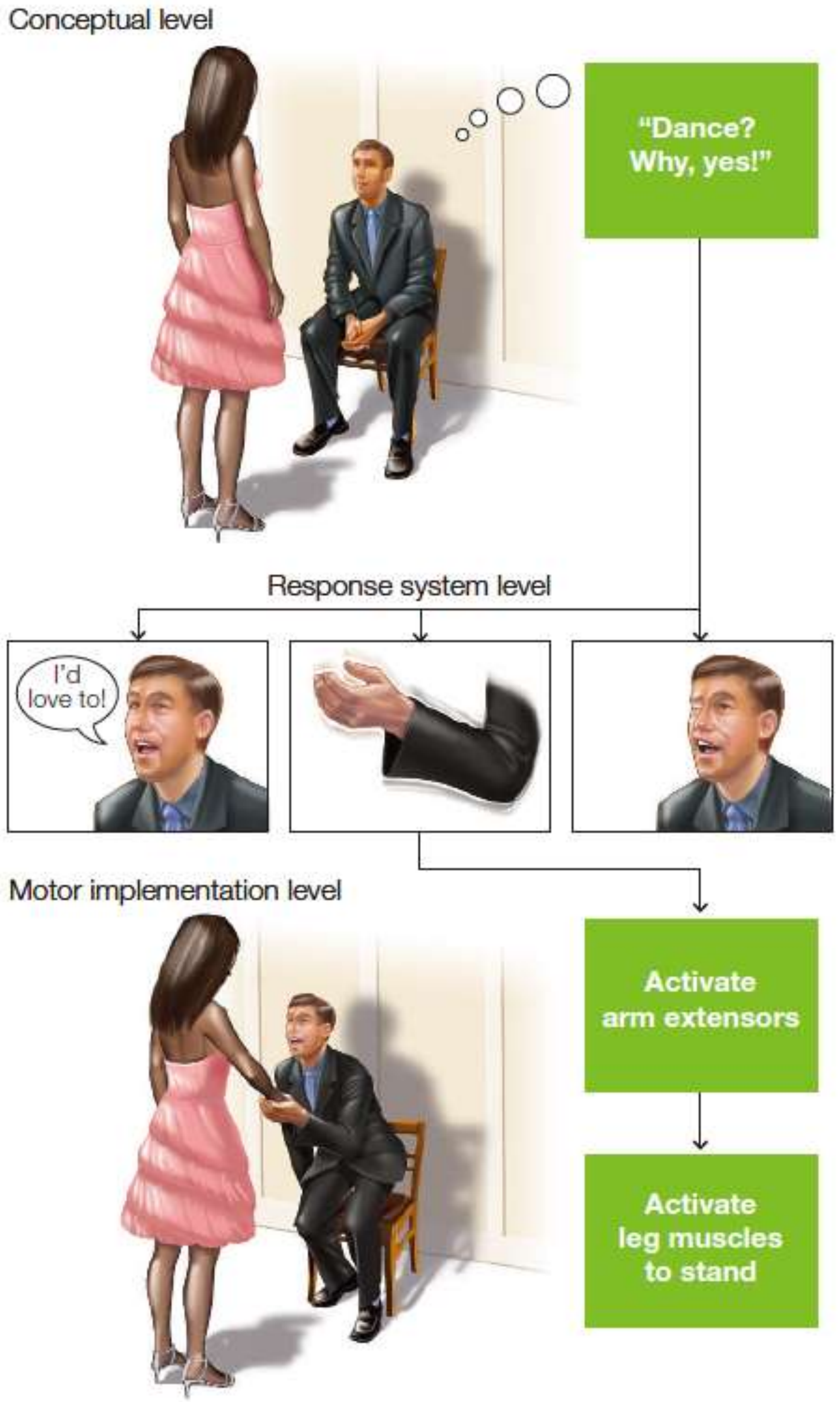
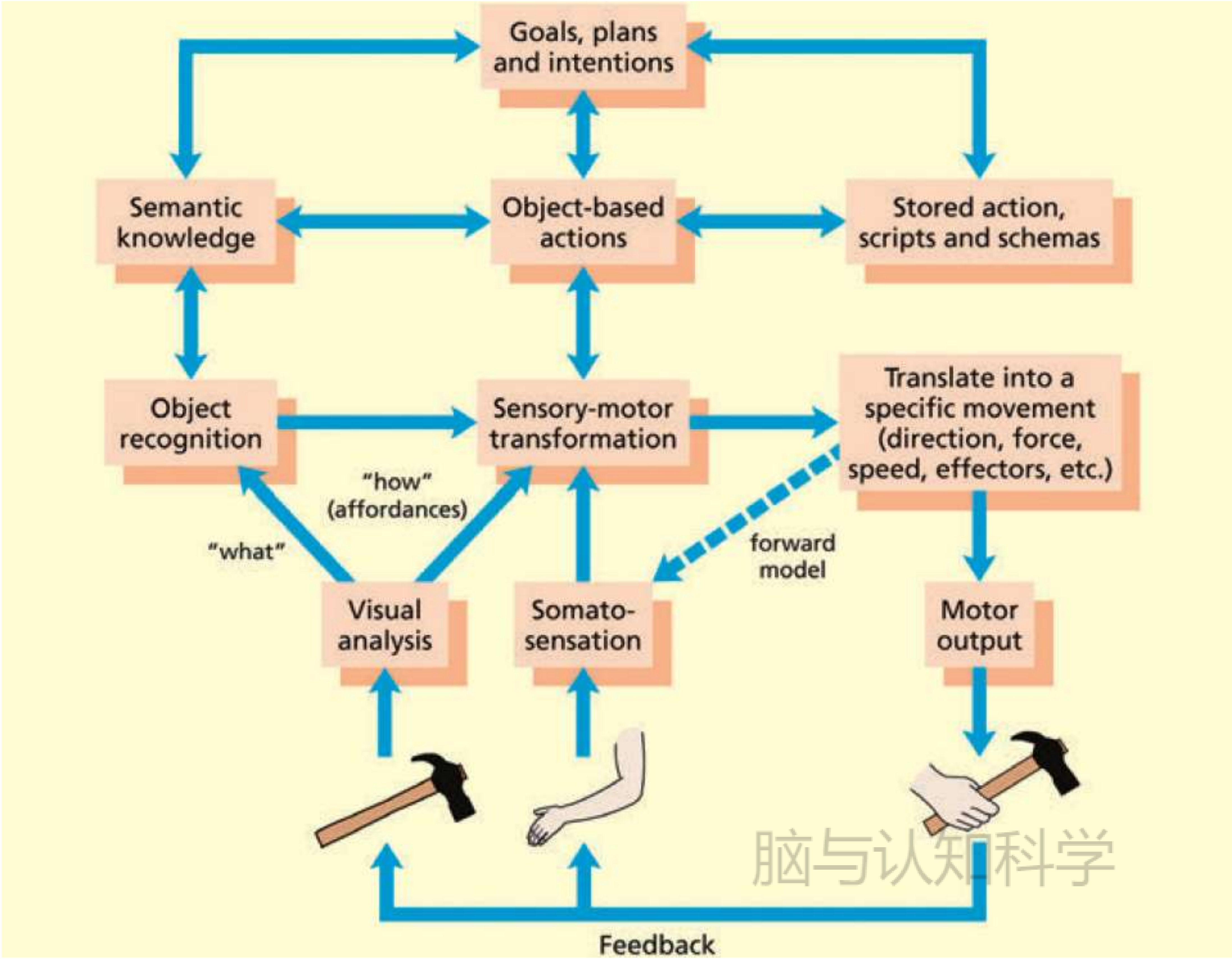
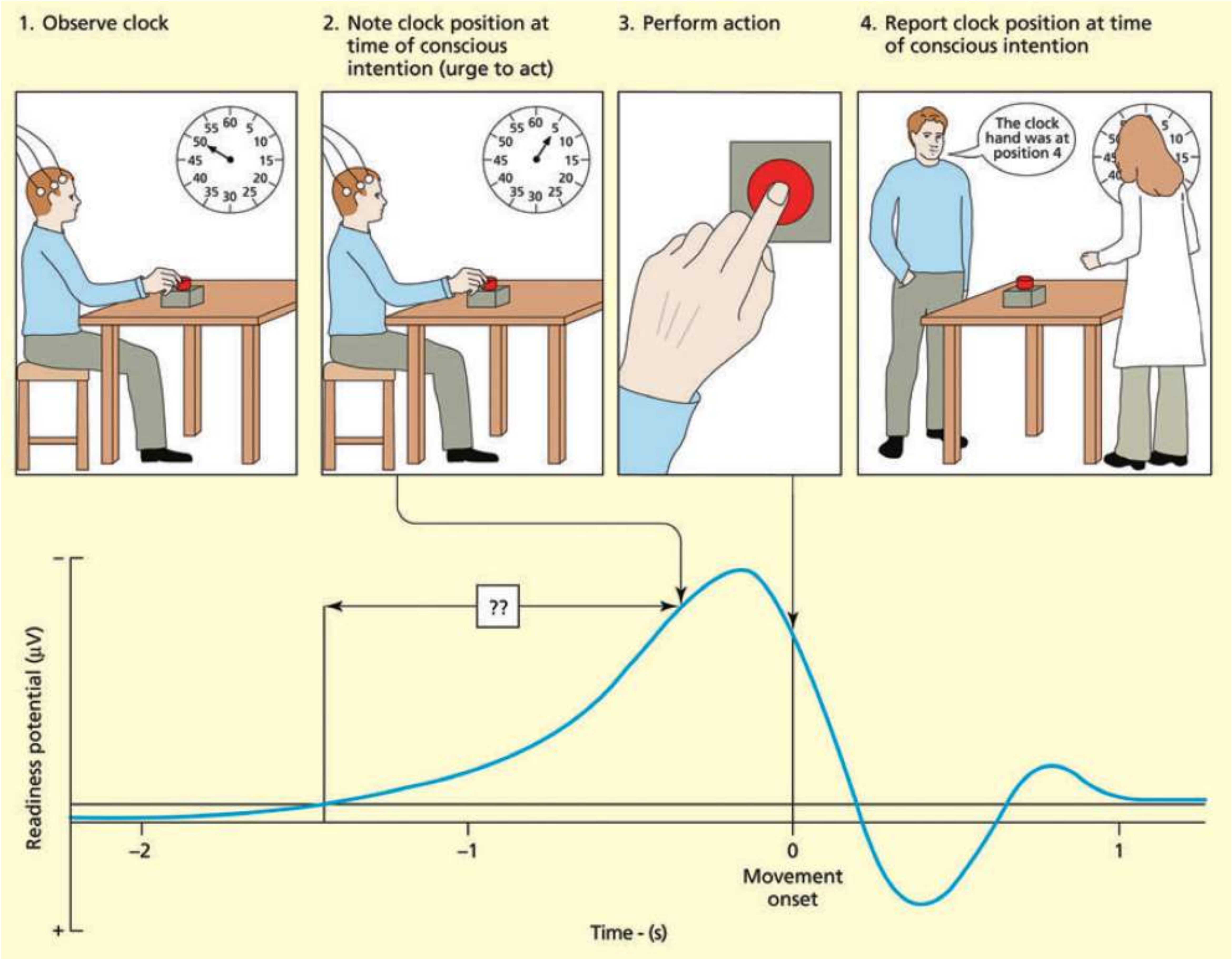
Cognitive framework for action





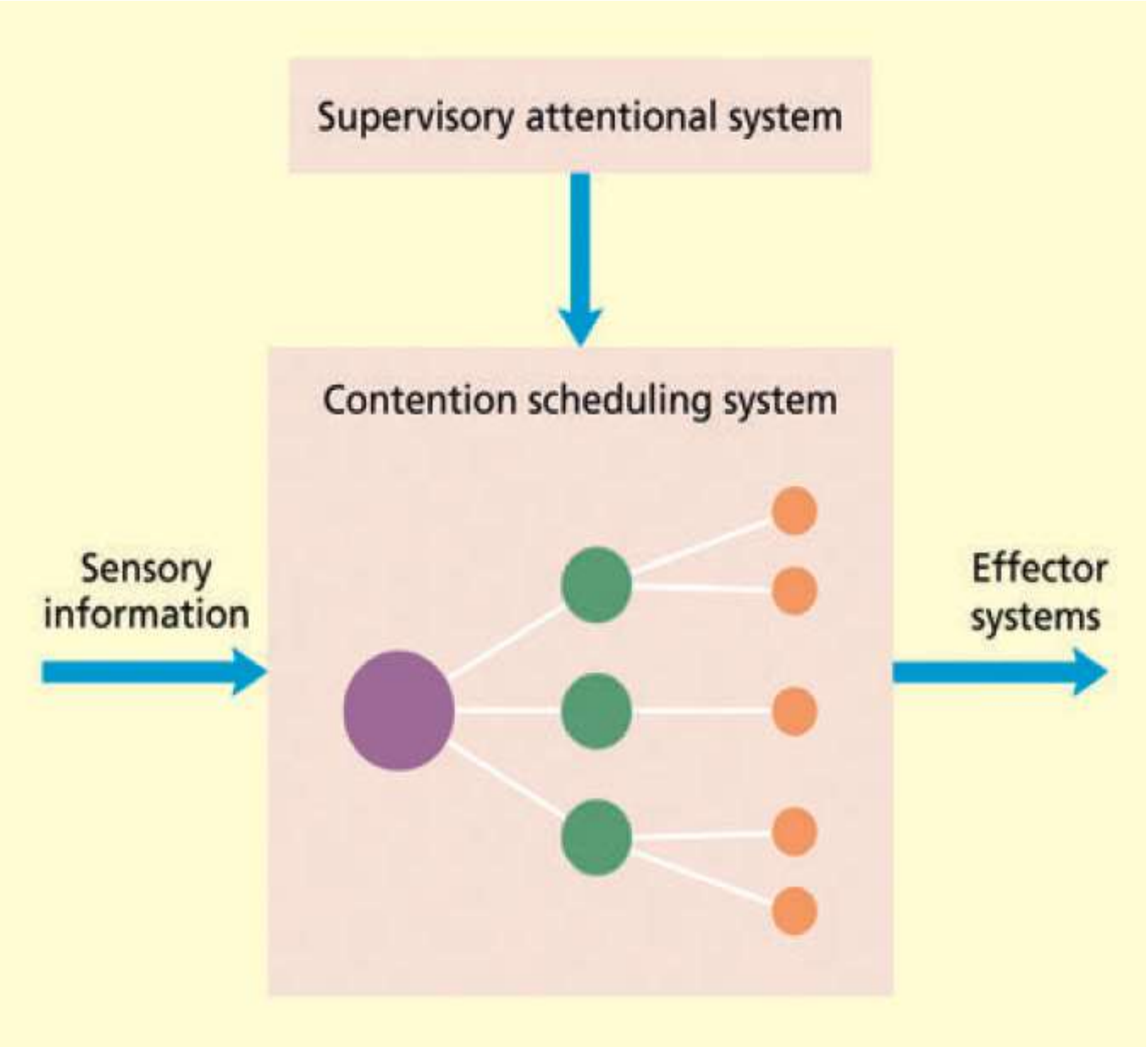
Awareness of actions



- The motor cortex generates a readiness potential long before the participant declares an **intention** to act.
- The results appeared to suggest that the brain had made an **unconscious** commitment to act before participants experienced a conscious intention to act.

Planning actions: supervisory attentional system(SAS)

SAS, a model to explain goal-driven action.

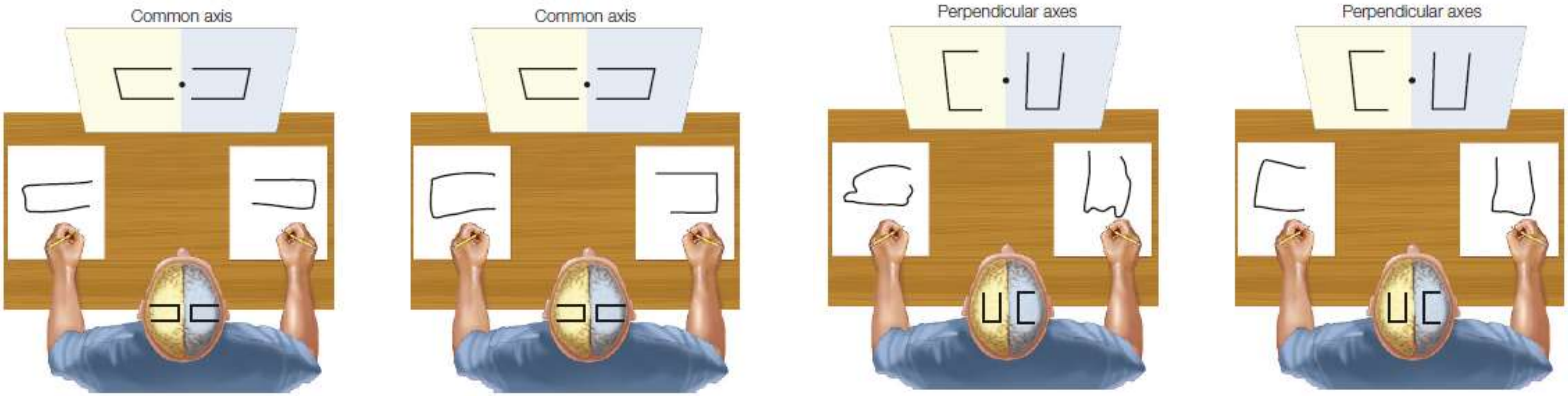


Schema: An organized set of stored information (e.g. of familiar action routines).
Contention scheduling: The mechanism that selects one particular schema to be enacted from a host of competing schemas

In SAS model, contention scheduling selects the most active schema.

The activation of schemas depends partly on the environment (derived from sensory input) and partly on the biasing influence of current and future goals.

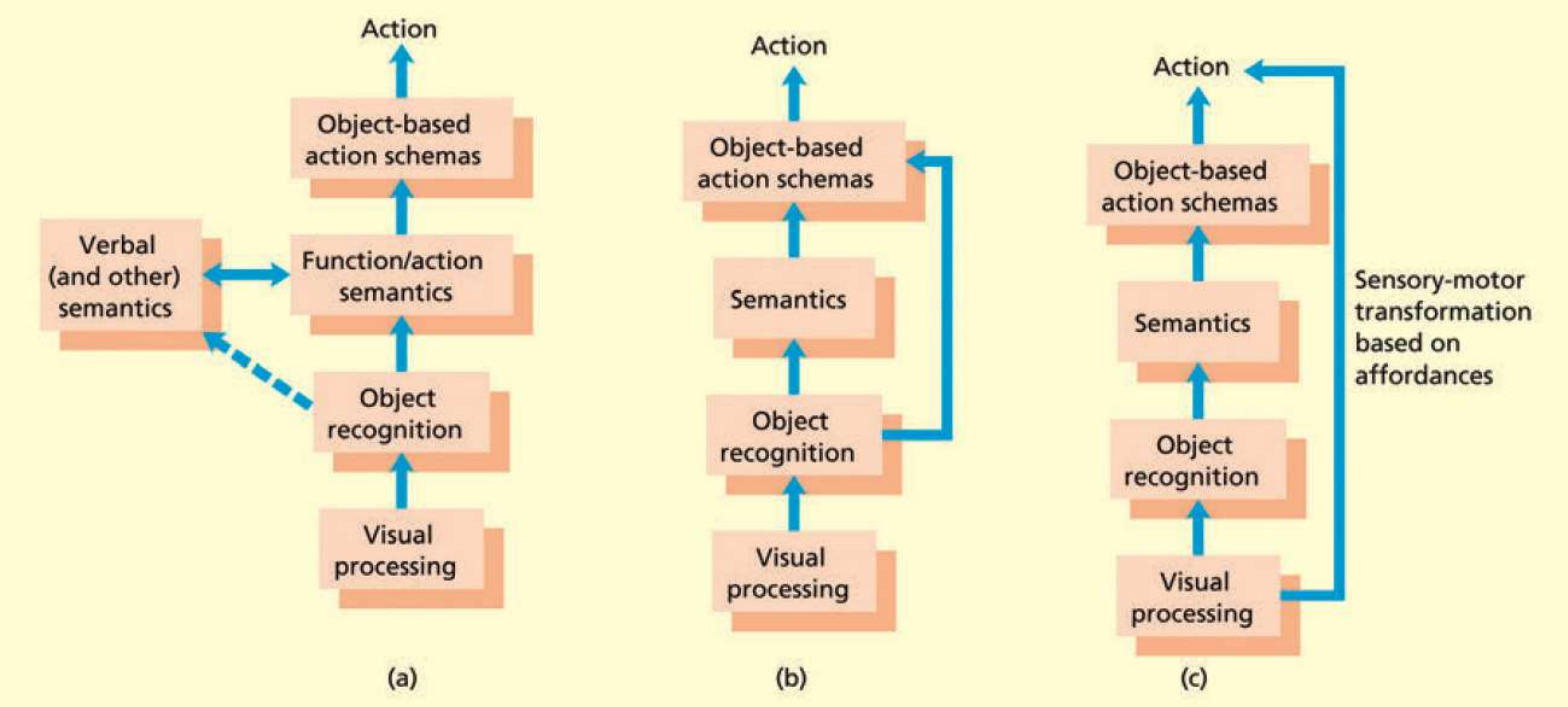
Movement plans



Intact corpus callosum | Callostomy patient | Intact corpus callosum | Callostomy patient

Normal participants were able to draw the patterns that shared a common axis but had severe difficulty when the orientation of the two figures differed by 90° . A callostomy patient performed equally well in both conditions. These results reveal cross talk between the two hemispheres during some stage of motor planning, most likely at the stage when an abstract action goal is being translated into a movement plan.

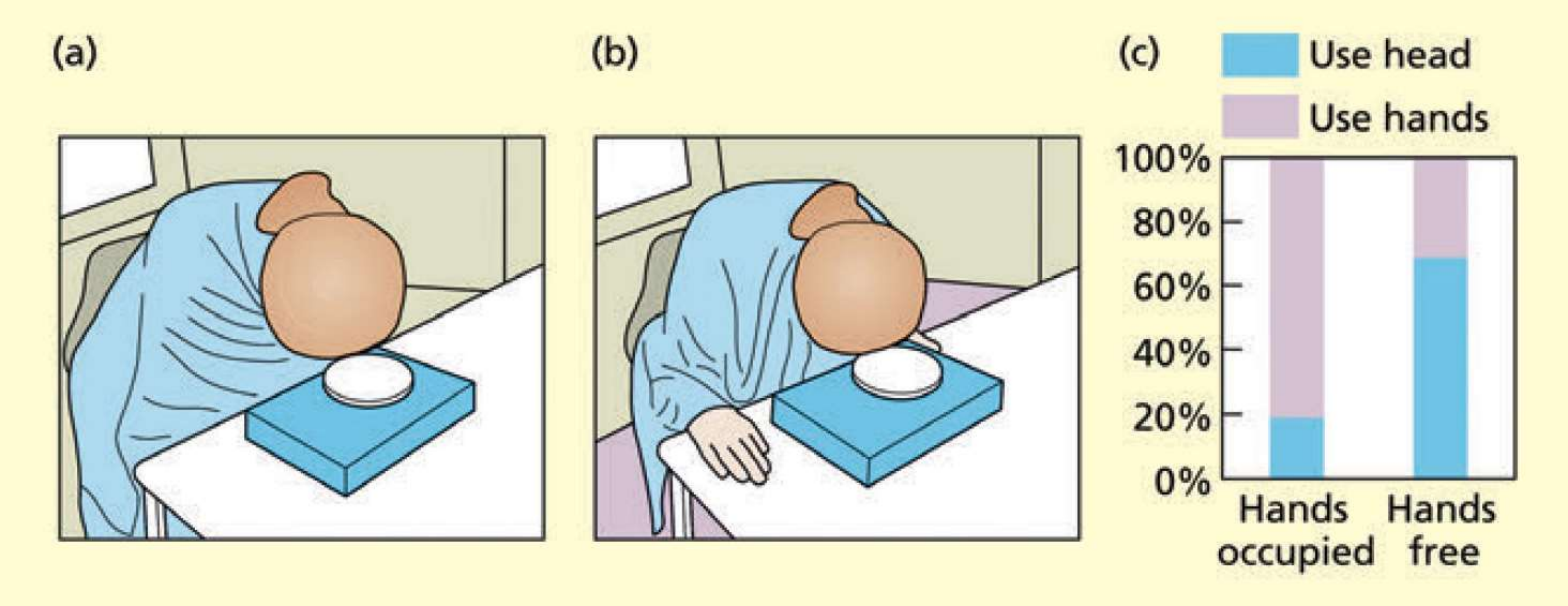
Models for object-related actions



Some patients can gesture the use of objects despite poor understanding and naming ability for those objects. This can be explained in three ways: fractionated semantic knowledge (a), direct links between stored object and action representations (b), or affordances related to non-arbitrary correspondences between visual features and motor commands (c).

Understand action from others

- **Mimicry**: reproduce an action via sensorimotor transformations that do not make any inferences about the goals and intentions of the actor.
- **Imitation**: observe the action, compute the goals and intentions of the actor and then reproduce the actions oneself based on the goal.
- Evidence suggests that humans tend to reproduce the actions of others by representing the **goal state** rather than by mimicry, particularly when the action is more complex.

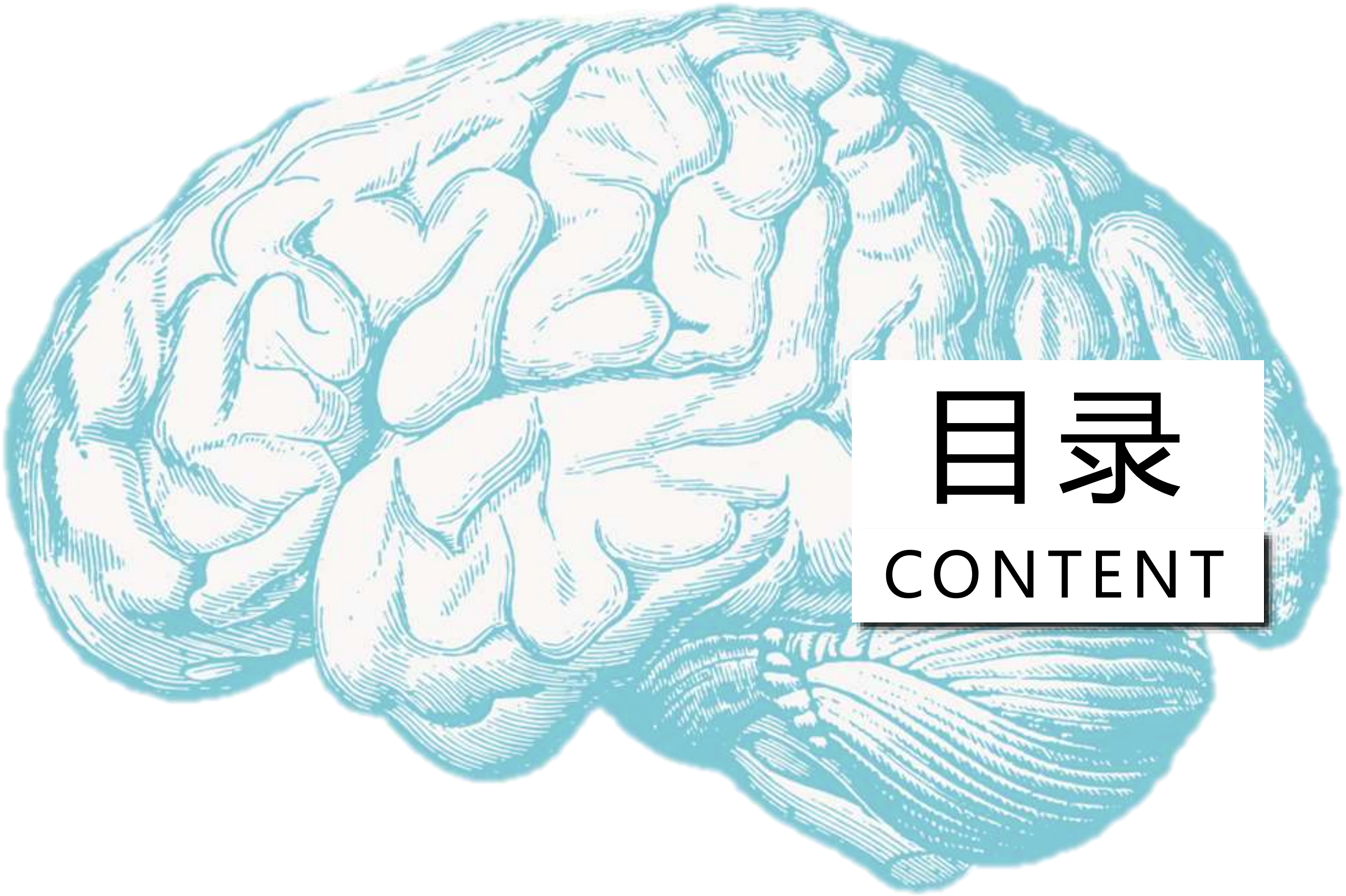


Infants imitate the goal of actions rather than the motor aspects of actions.

Reproduce the actions of another person: mirror neurons

a Static   b Shooting the basketball   c Kicking a soccer ball

Relative to the static condition (a), basketball players and expert observers showed an increase in arm muscle MEPs when observing the player shooting a basketball (b), but not when observing him kick a soccer ball (c). Novices showed weaker activations in all conditions.



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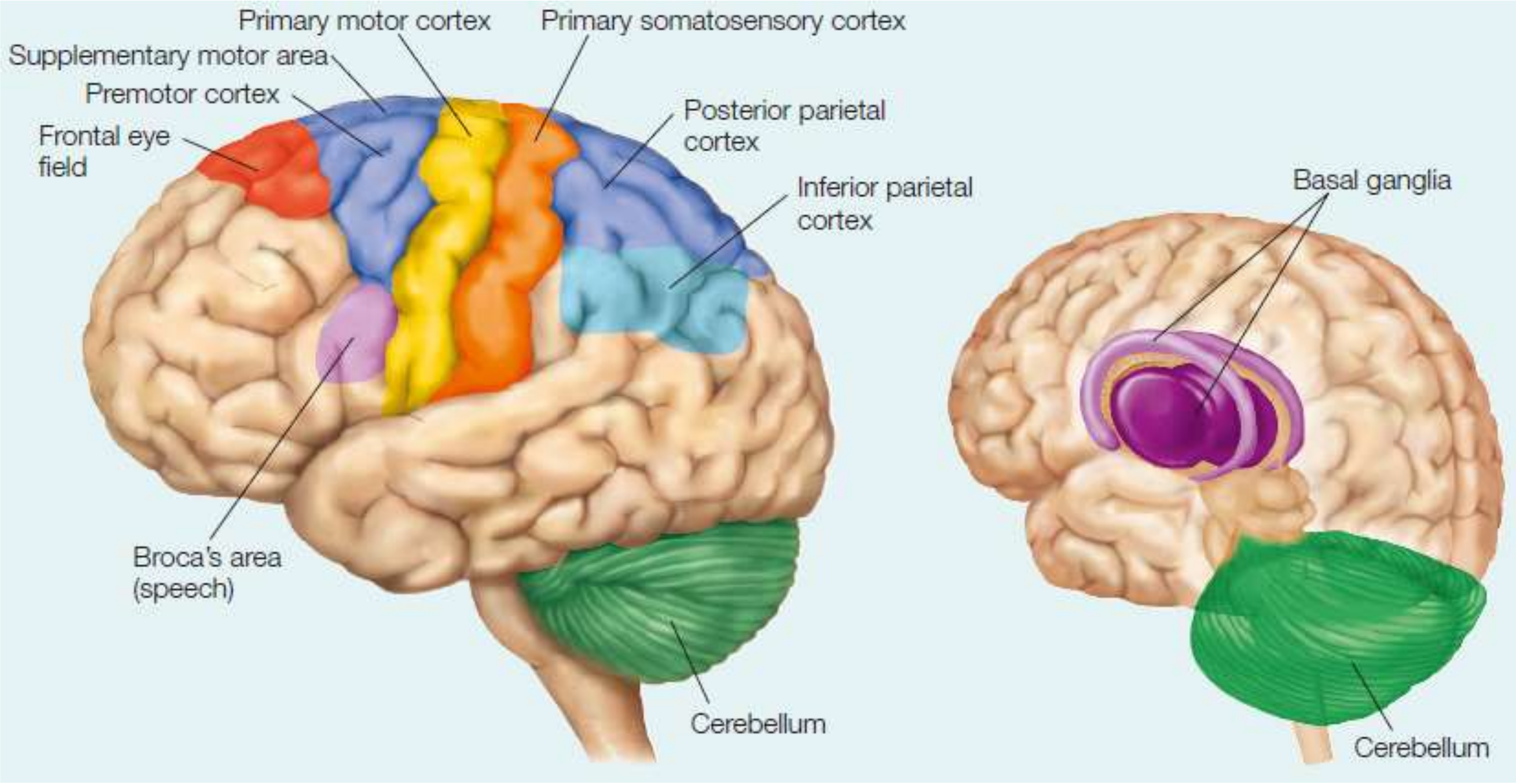
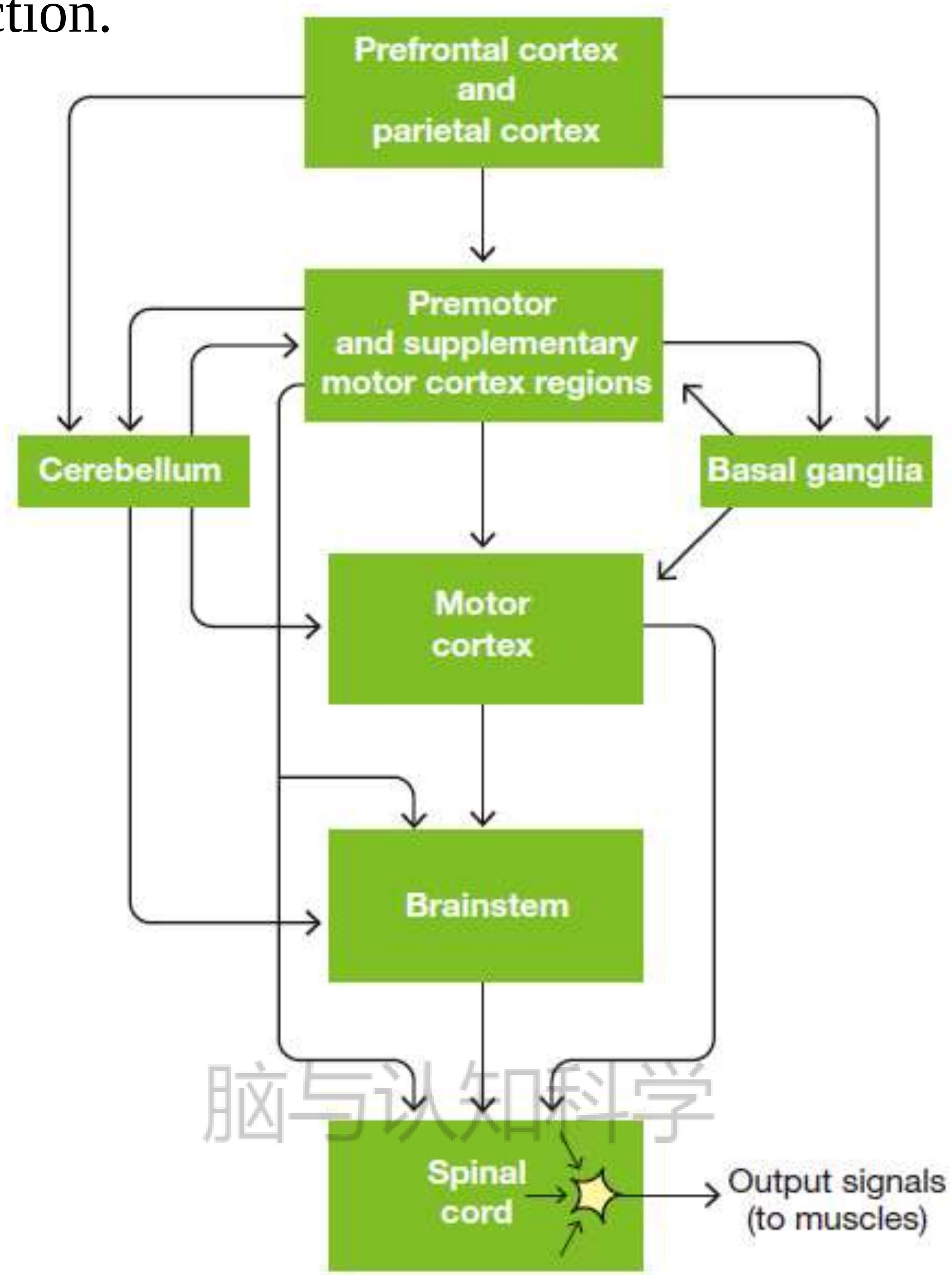
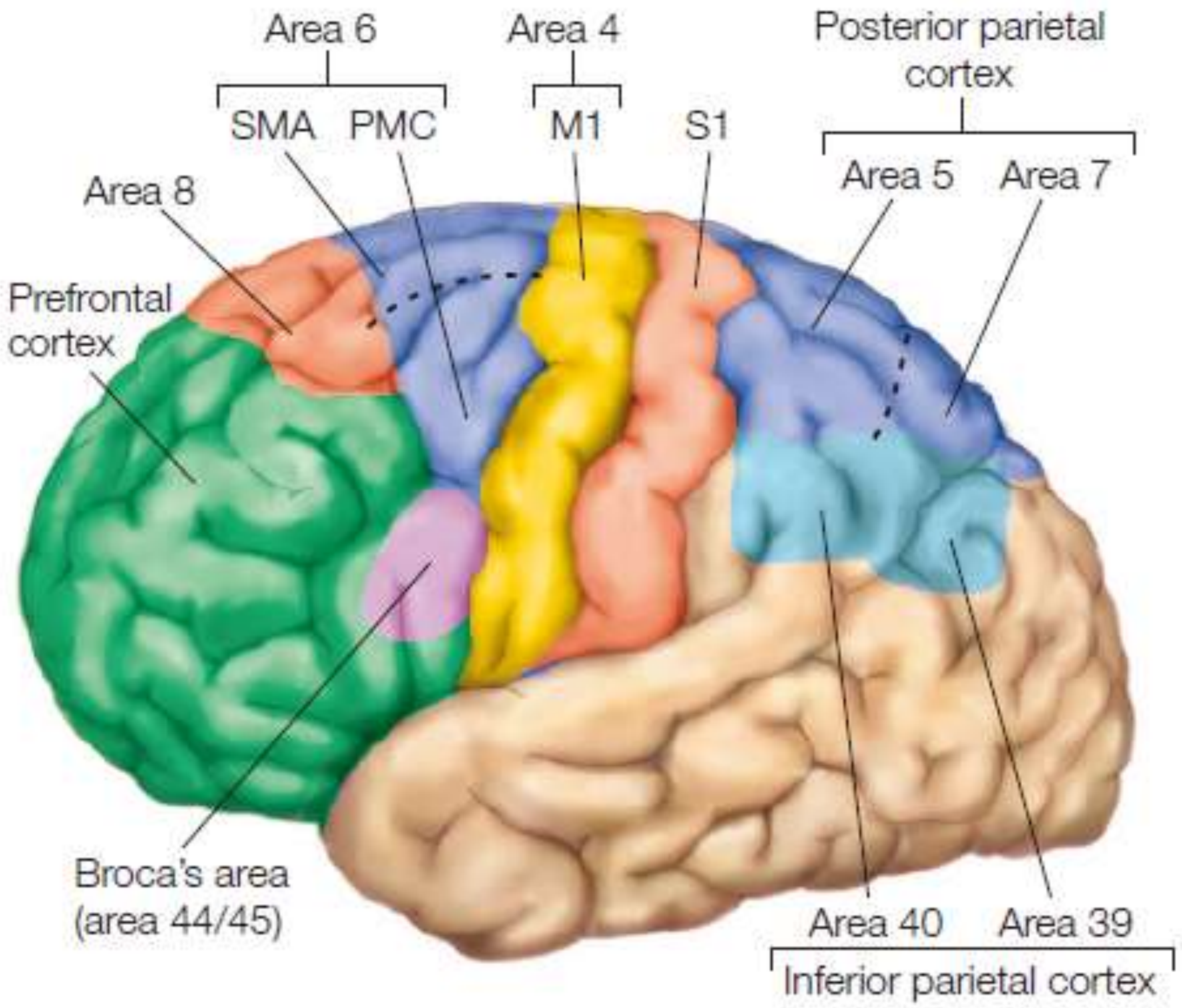
Anatomy of Action

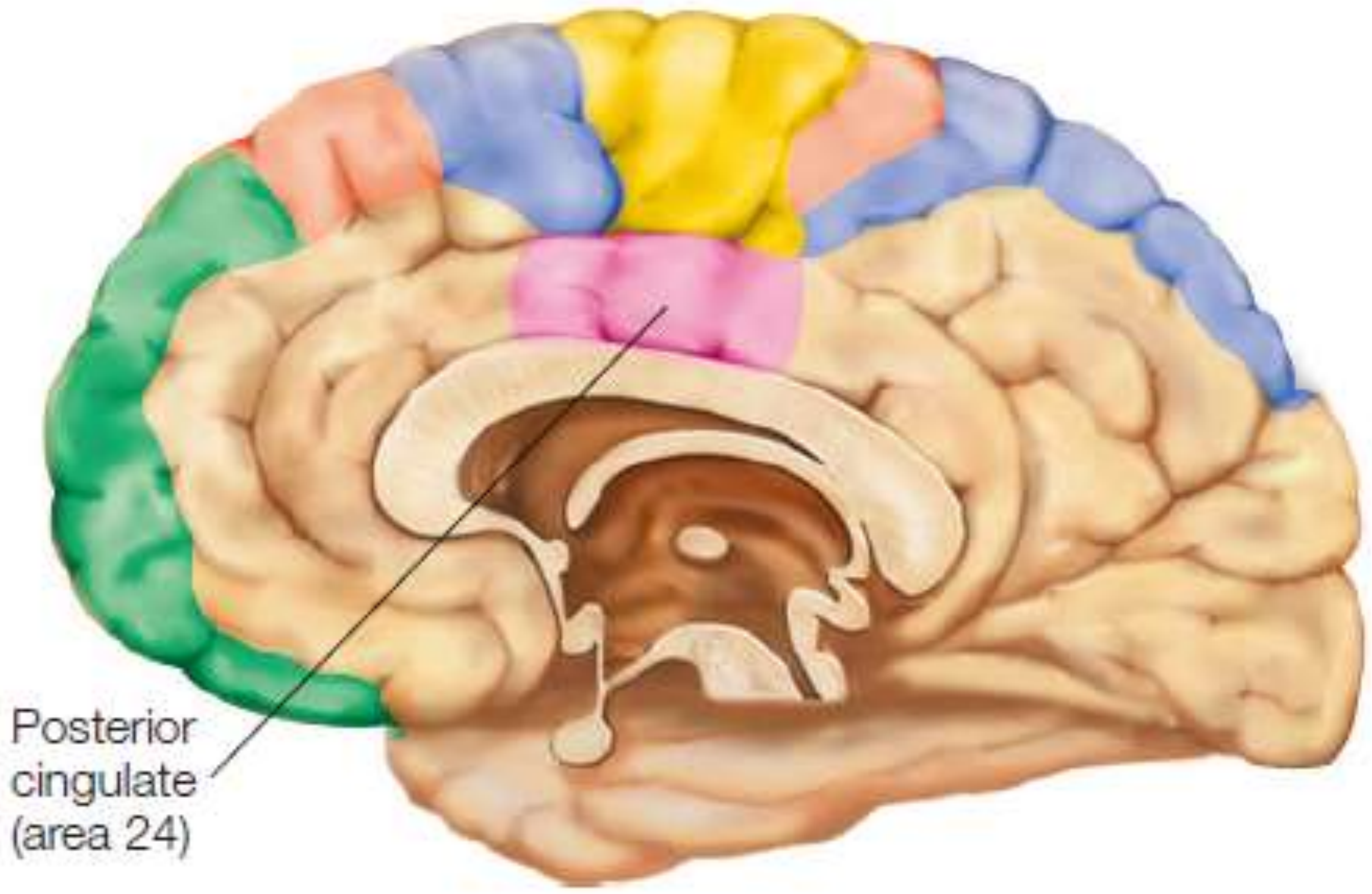
Many cortical regions are involved in **planning**, **control**, and **execution** of movement. In addition, two major subcortical structures of the motor system are the cerebellum and the basal ganglia. The motor system is hierarchically organized. Subcortical and cortical areas represent movement goals at various levels of abstraction.





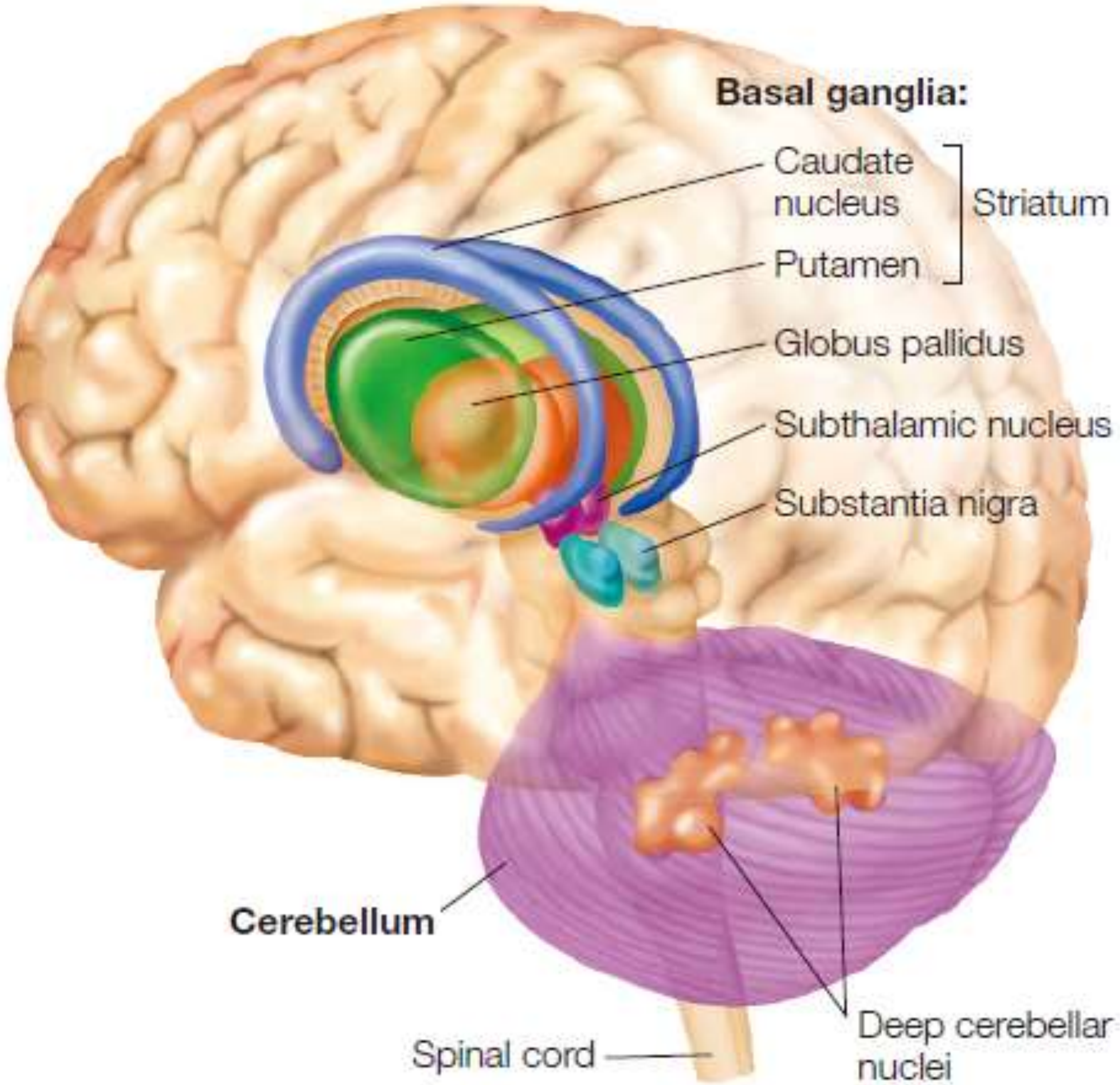
Motor areas of the cerebral cortex.





Brodmann area 4 is the primary motor cortex (M1). Area 6 encompasses the supplementary motor area (SMA) on the medial surface, as well as premotor cortex (PMC) on the lateral surface. Area 8 includes the frontal eye fields. Inferior frontal regions (area 44/45) are involved in speech. Regions of parietal cortex associated with the planning and control of coordinated movement include primary (S1) and secondary somatosensory areas, and posterior and inferior parietal regions.

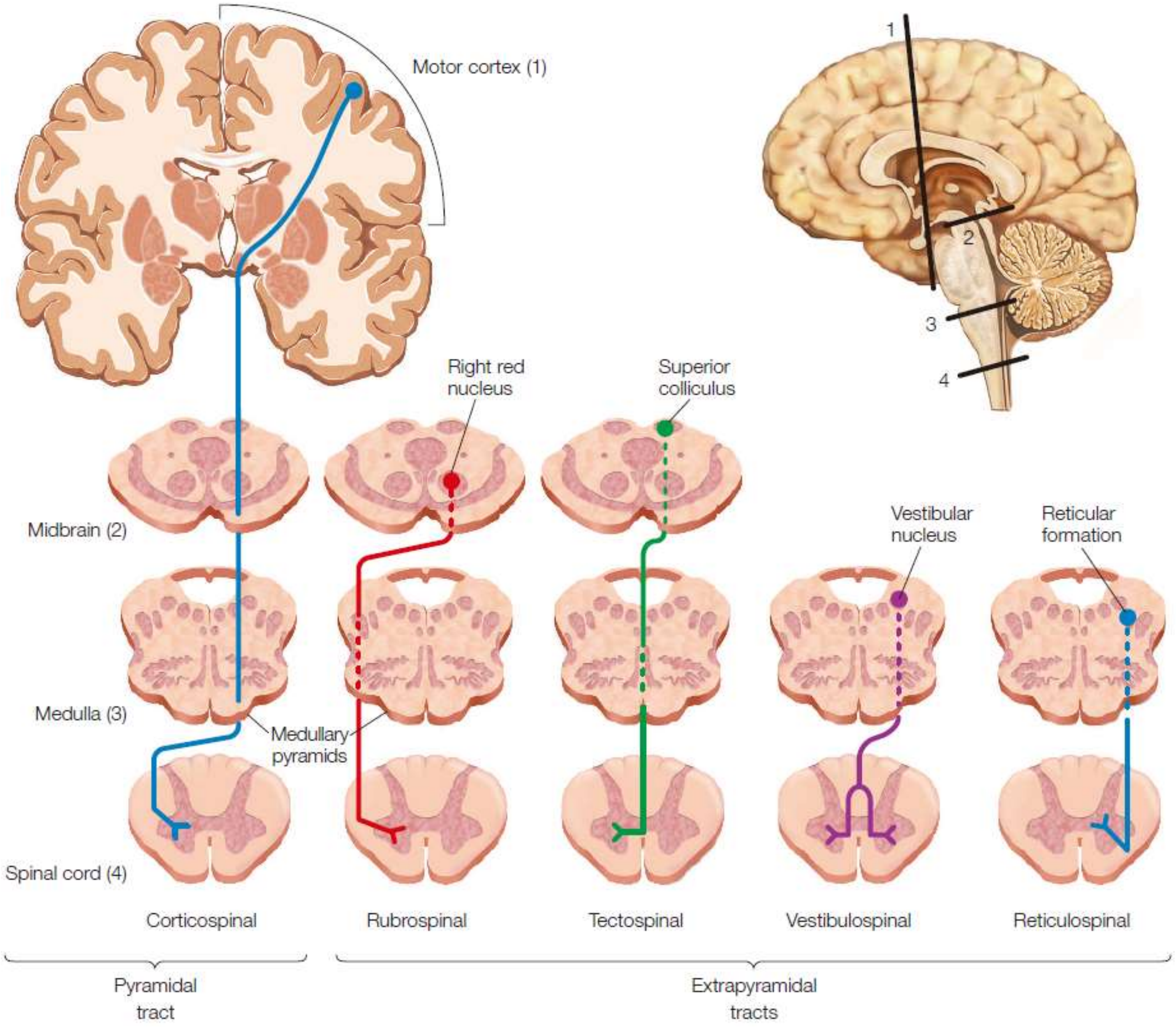
The basal ganglia and the cerebellum



- The basal ganglia proper include the caudate, putamen, and globus pallidus, three nuclei that surround the thalamus. Functionally, however, the subthalamic nucleus and substantia nigra are also considered part of the basal ganglia.

- The cerebellum sits below the posterior portion of the cerebral cortex. All cerebellar output originates in the deep cerebellar nuclei.

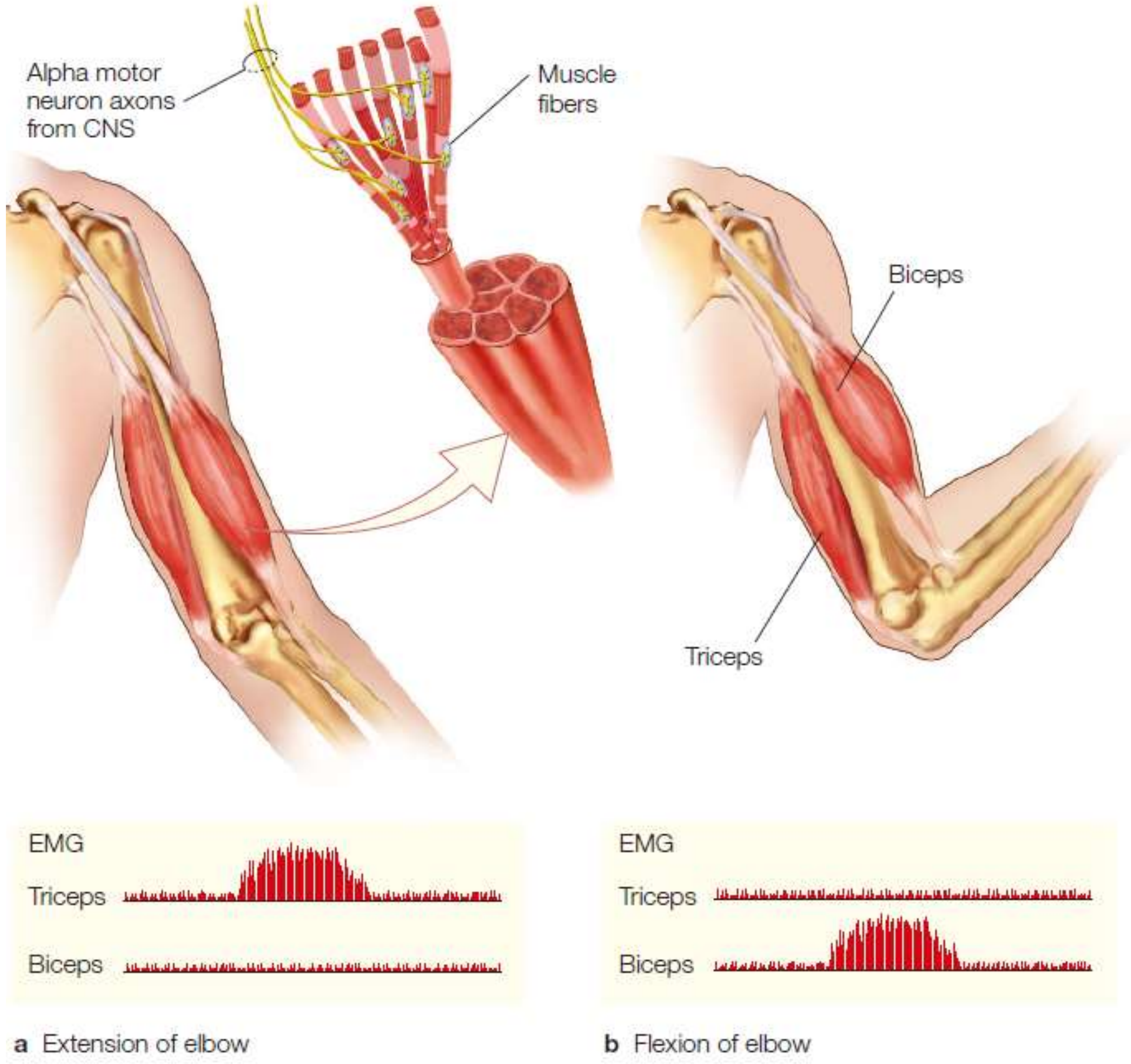
The spinal cord tracts

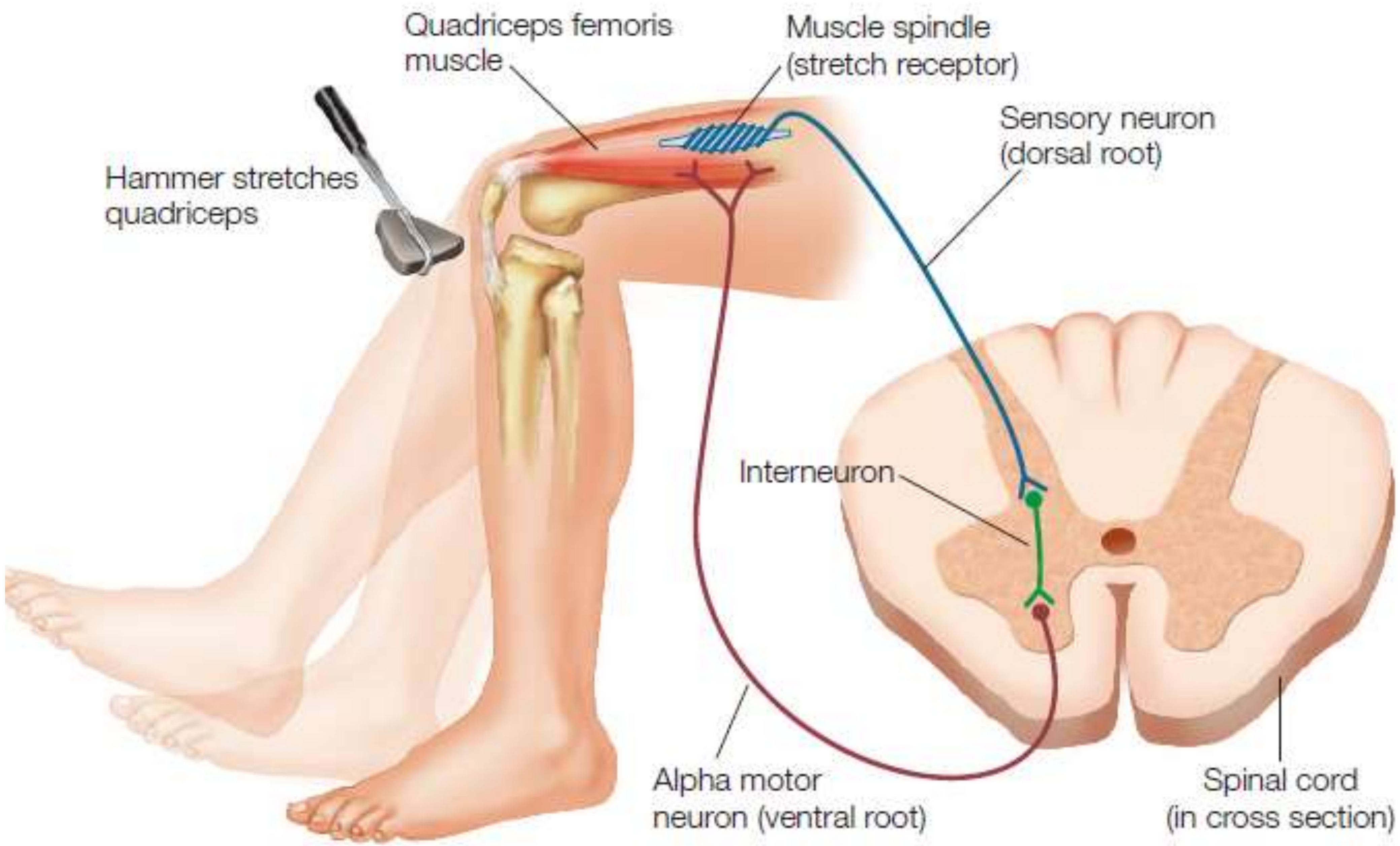


- The corticospinal or pyramidal tract is made up of descending fibers that originate in the cortex and project monosynaptically to the spinal cord, and cross over to the contralateral side at the medullary pyramids.

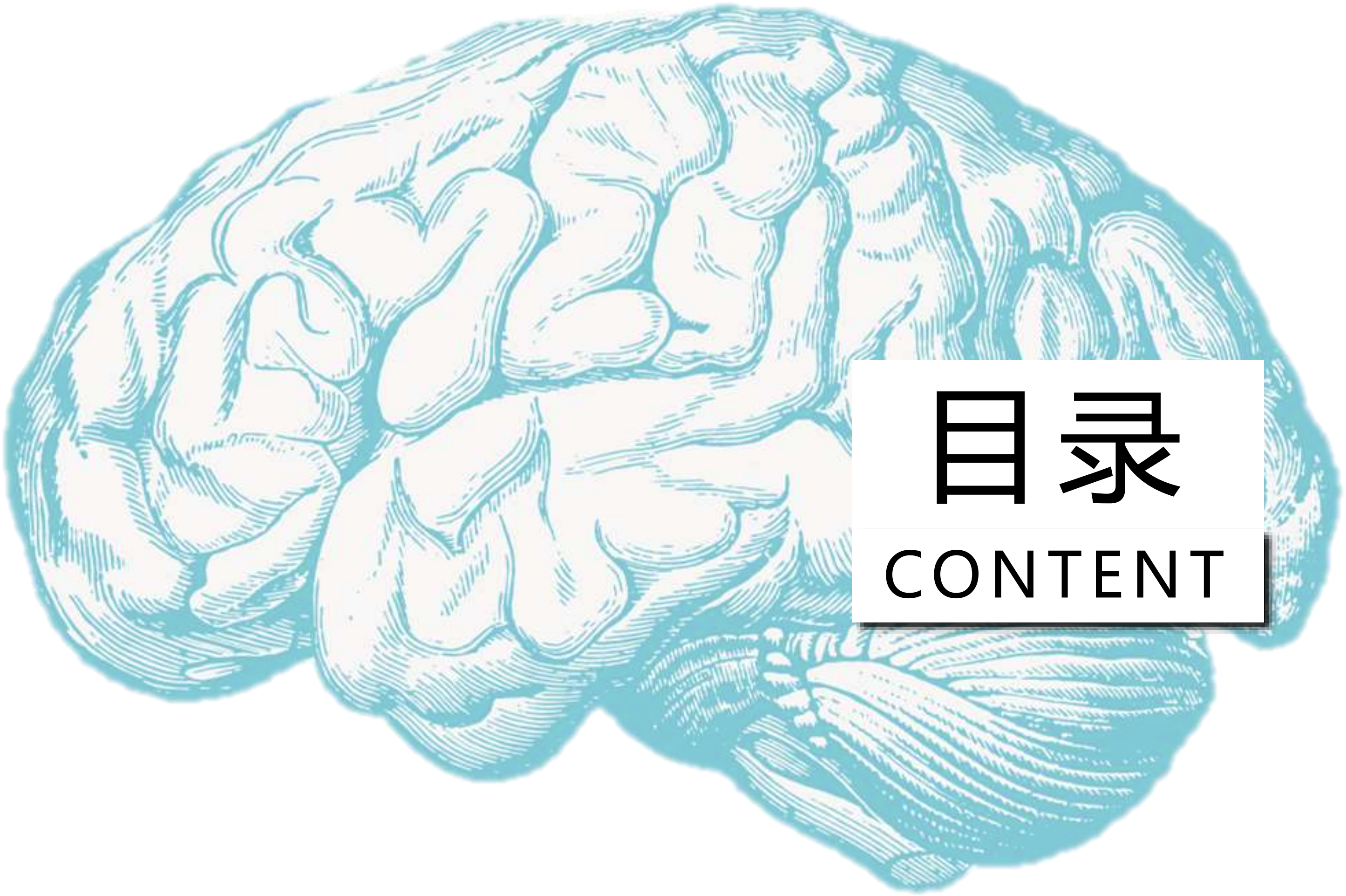
- Extrapyramidal tracts are neural pathways that project from the subcortex to the spinal cord, and terminate in both contralateral and ipsilateral regions of the spinal cord.

Muscles





Alpha motor neurons provide the point of translation between the nervous system and the muscular system, originating in the spinal cord and terminating on muscle fibers. Action potentials in alpha motor neurons cause the muscle fibers to contract.



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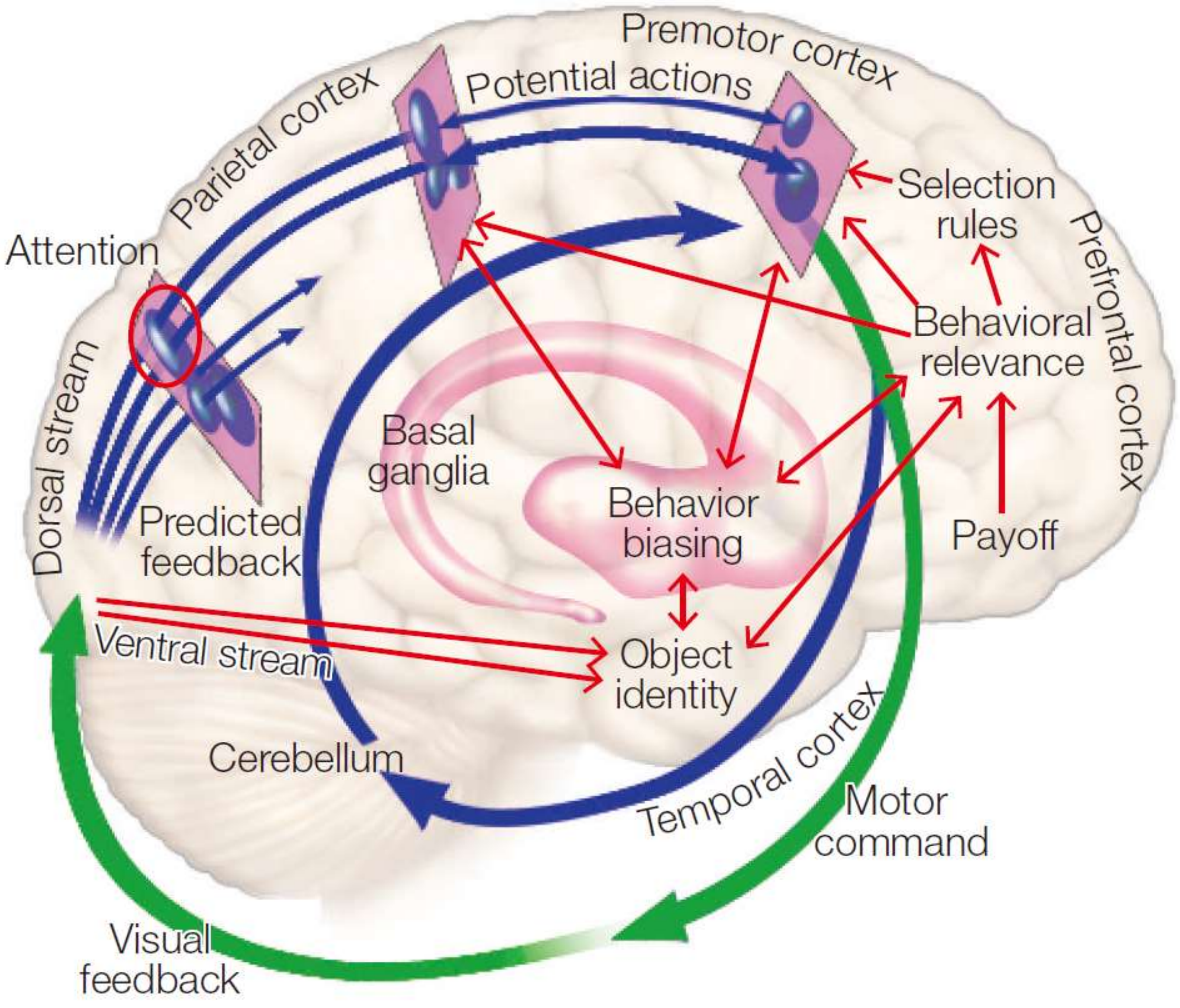
Action goals and movement plans

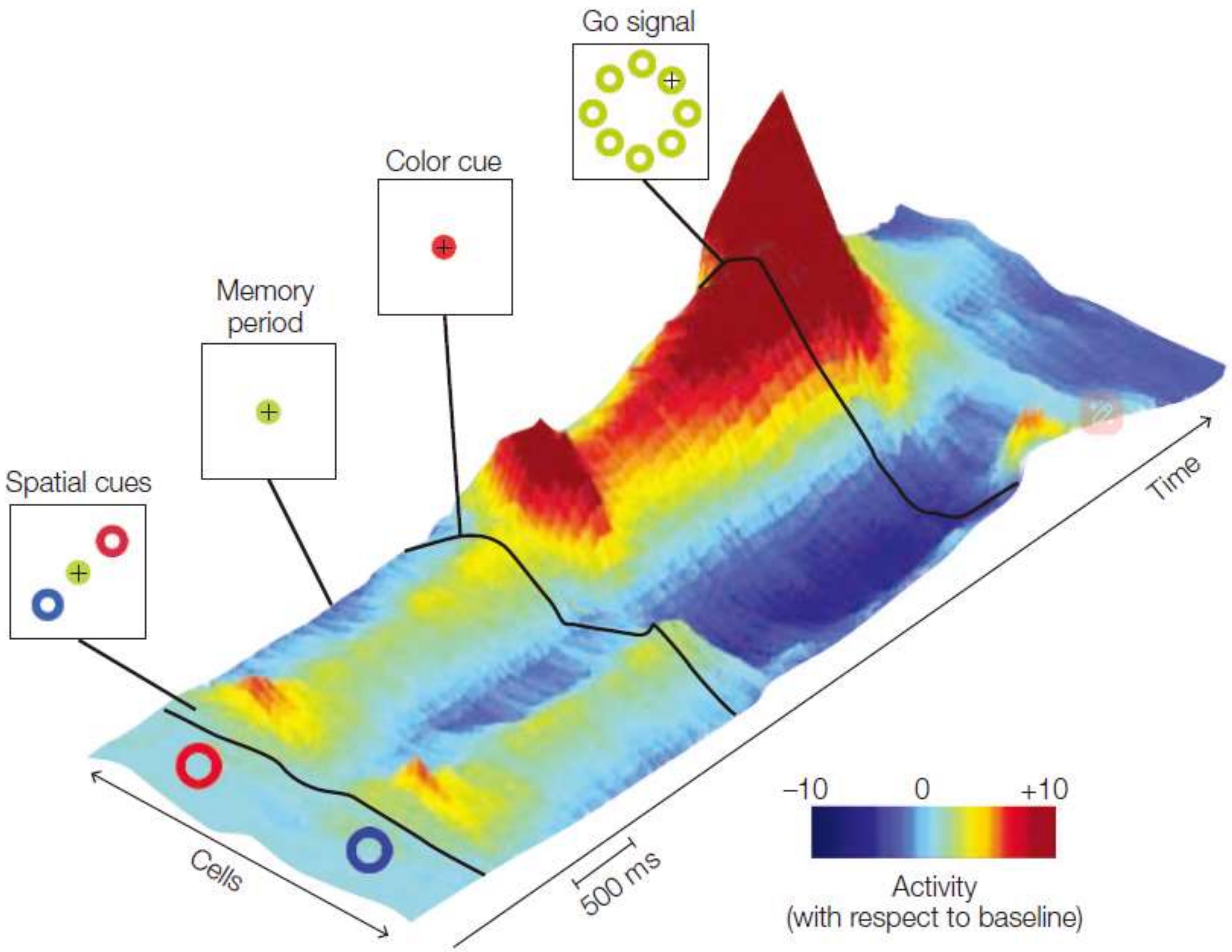
The affordance competition hypothesis



- This schematic shows the processes and pathways involved in choosing to **reach for one object among many objects** in a display. The multiple pathways from visual cortex across the dorsal stream correspond to action plans for reaching to the different objects.
- The relative thickness of the blue arrows and circles indicates the strength for each competing plan. Selection is influenced by many sources (red arrows). The movement (green arrows) results in visual feedback of the action, starting the competition a new, but now in a different context.

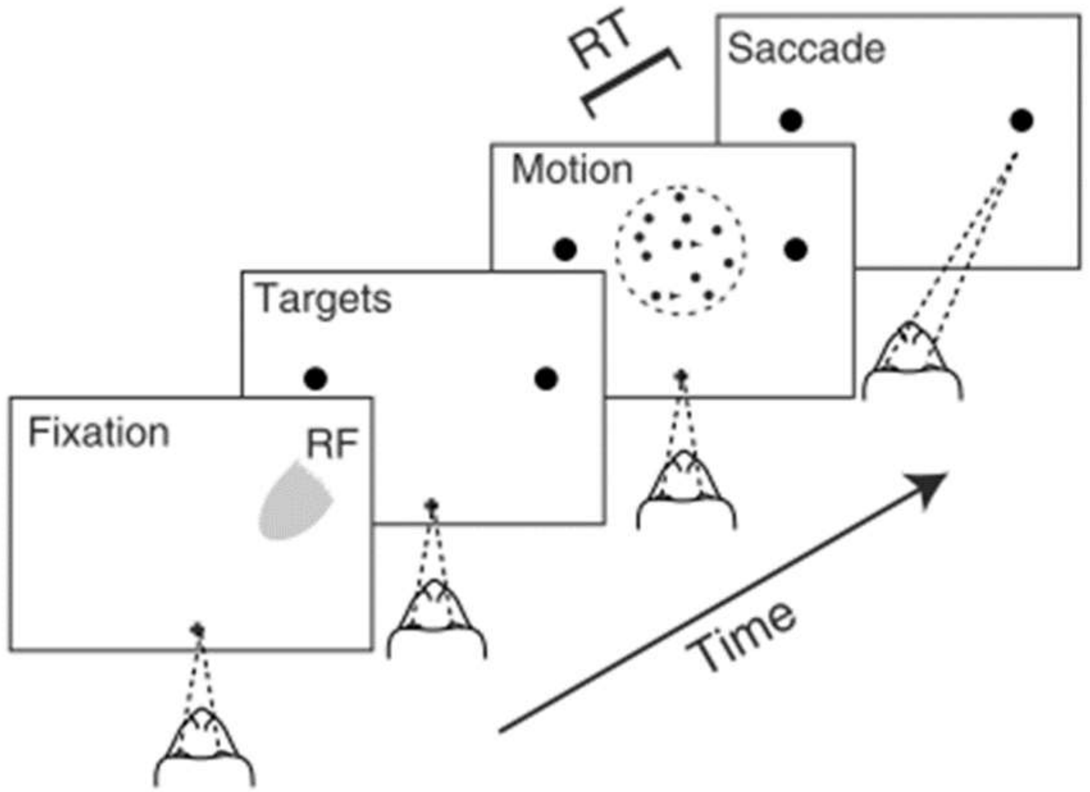
Planning and executing movements

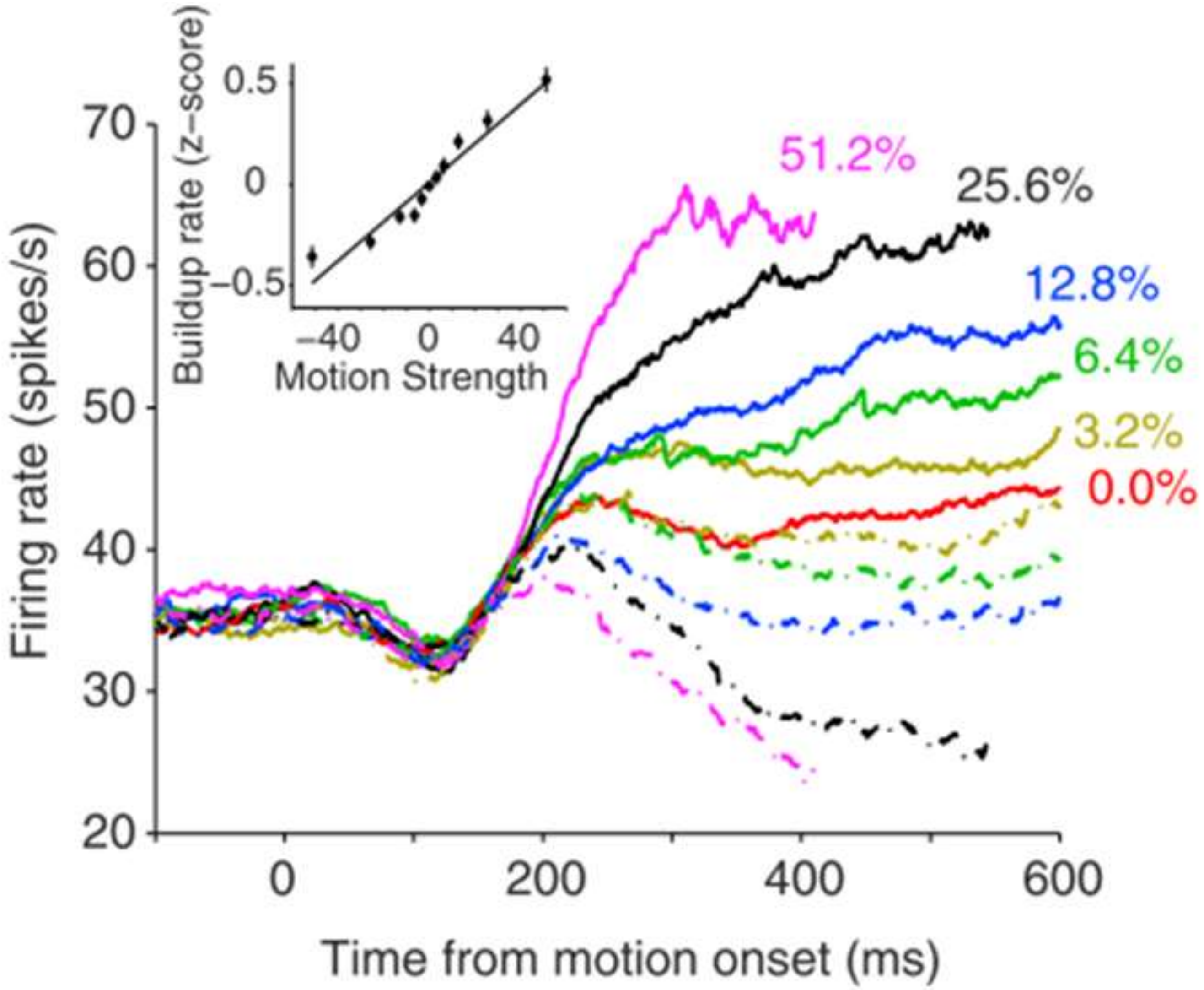
Planning are embedded in the neural systems associated with motor control, not carried out by some sort of detached central control center.

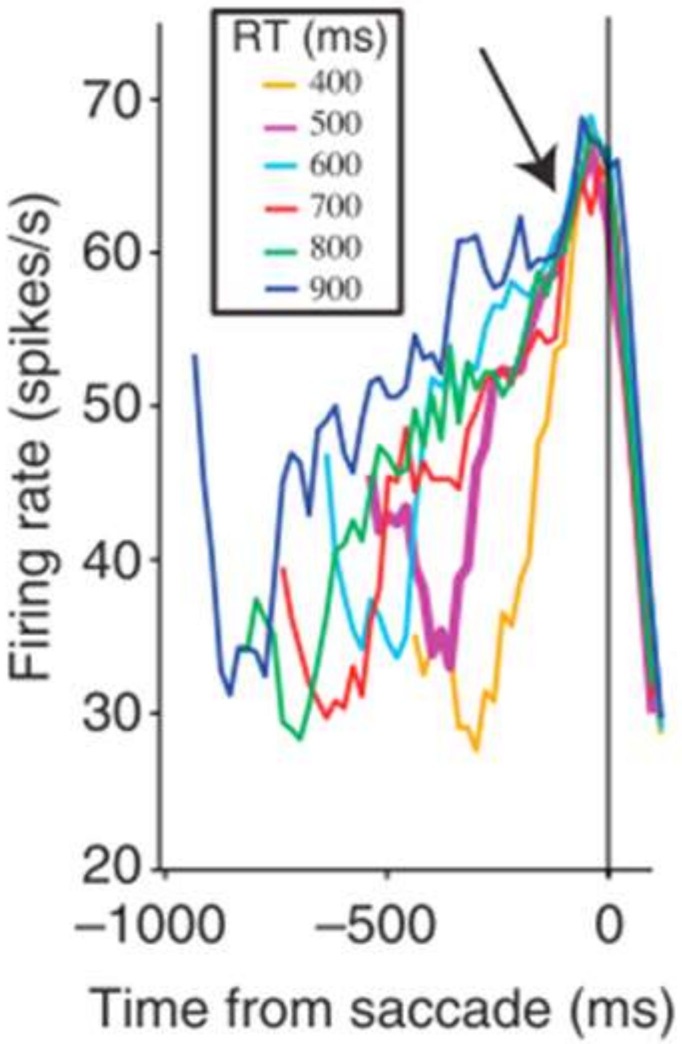


The preferred direction of the cells is represented along the bottom left of the figure; time, along the bottom right. When the two spatial cues appear, the firing rate increases in neurons tuned to either target. When the color cue appears, indicating the target, activity increases for cells tuned to this direction and decreases for cells tuned to the other direction. The go signal indicated to the monkey when to initiate movement.

Response of LIP neurons during decision formation.





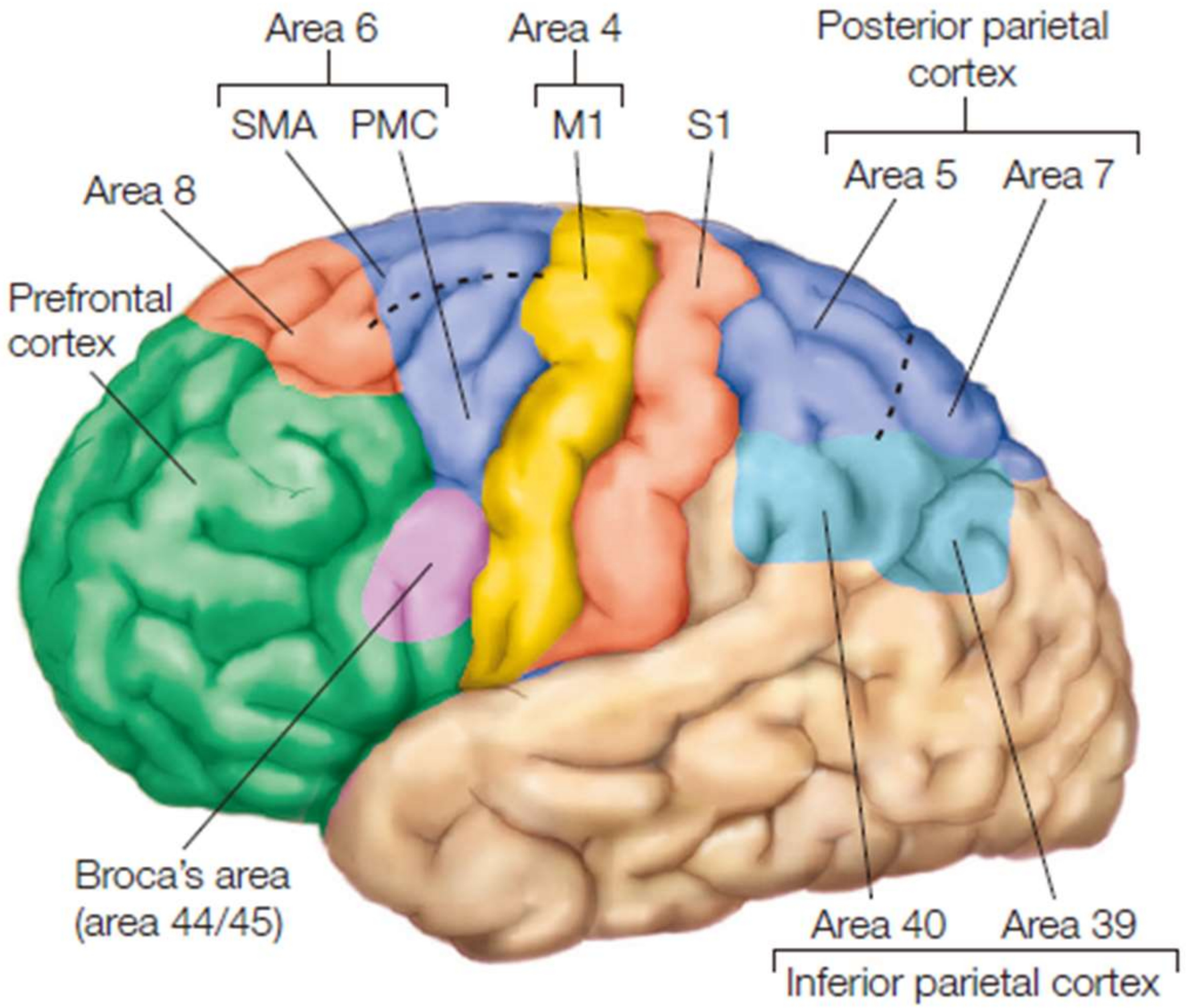


The monkey decides the net direction of motion, indicating by an eye movement to a peripheral target.

Firing rates are aligned to **onset of RDM** and truncated at the median RT.

Responses grouped by reaction time and aligned to **the onset of eye movement**.

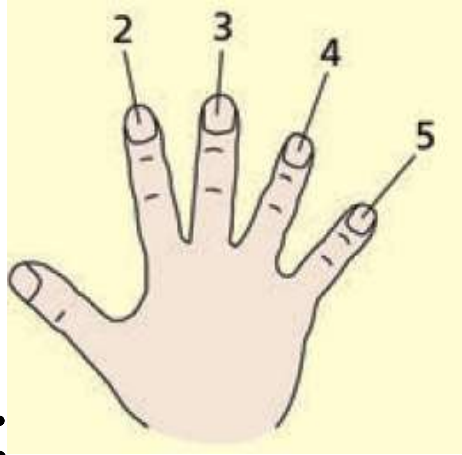
Premotor cortex: lateral vs. medial



- The medial premotor cortex has been associated with dealing with spontaneous, well-learned actions, particularly action sequences that do not place strong demands on monitoring the environment.
- The lateral premotor cortex is important for linking action with visual objects in the environment.
- The lateral premotor cortex receives visual signals via the parietal cortex, whereas the medial premotor cortex (SMA) receives strong proprioceptive signals concerning the current position of the limbs.

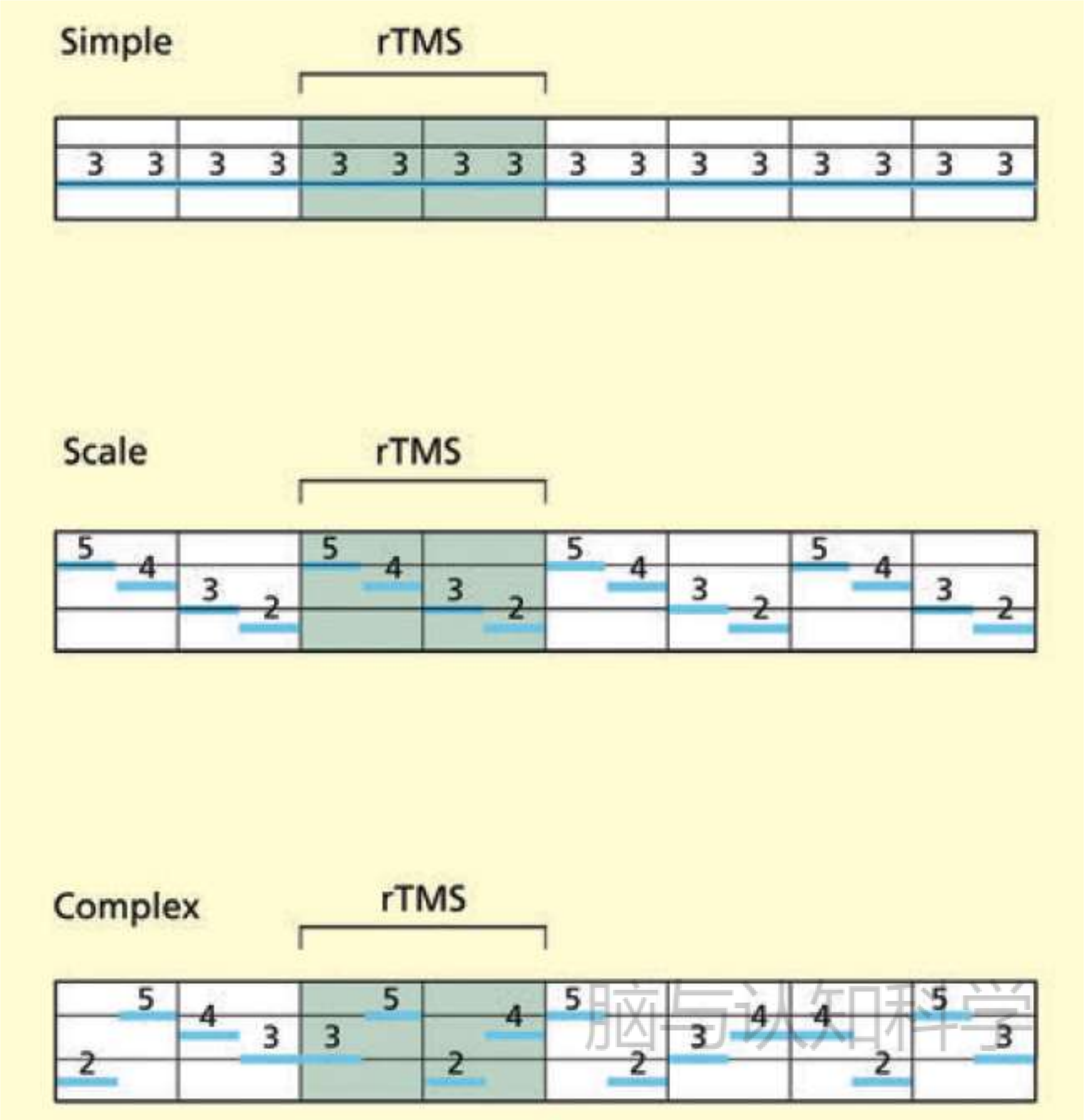
TMS effects on premotor and SMA

- TMS over the primary motor cortex affected both “complex” and “scale” action sequences;

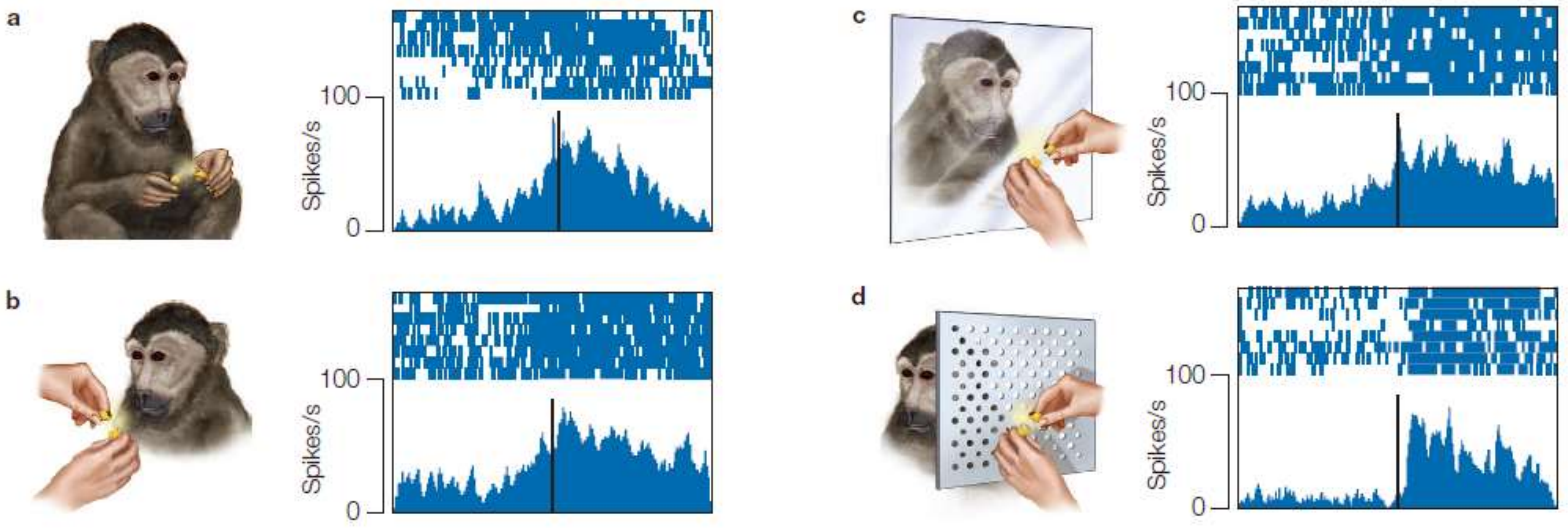


- TMS over the lateral prefrontal cortex had no effects.

- TMS over the SMA disrupted the sequence in the “complex” condition only



Reproduce the actions of another person: mirror neurons



Exactly the same neuron in the monkey ventral premotor cortex(F5) fired when an individual monkey observed the action of reaching for a peanut and when it performed the same action itself.

Neural mechanisms of sensorimotor transformation

- Neurons in area F5 that code **specific type**s of actions
  - A neuron that responds to performed finger movements for grasping may not discharge for scratching. Other neurons may be specialized for different types of hand shaping (e.g. precision grip, whole-hand prehension).

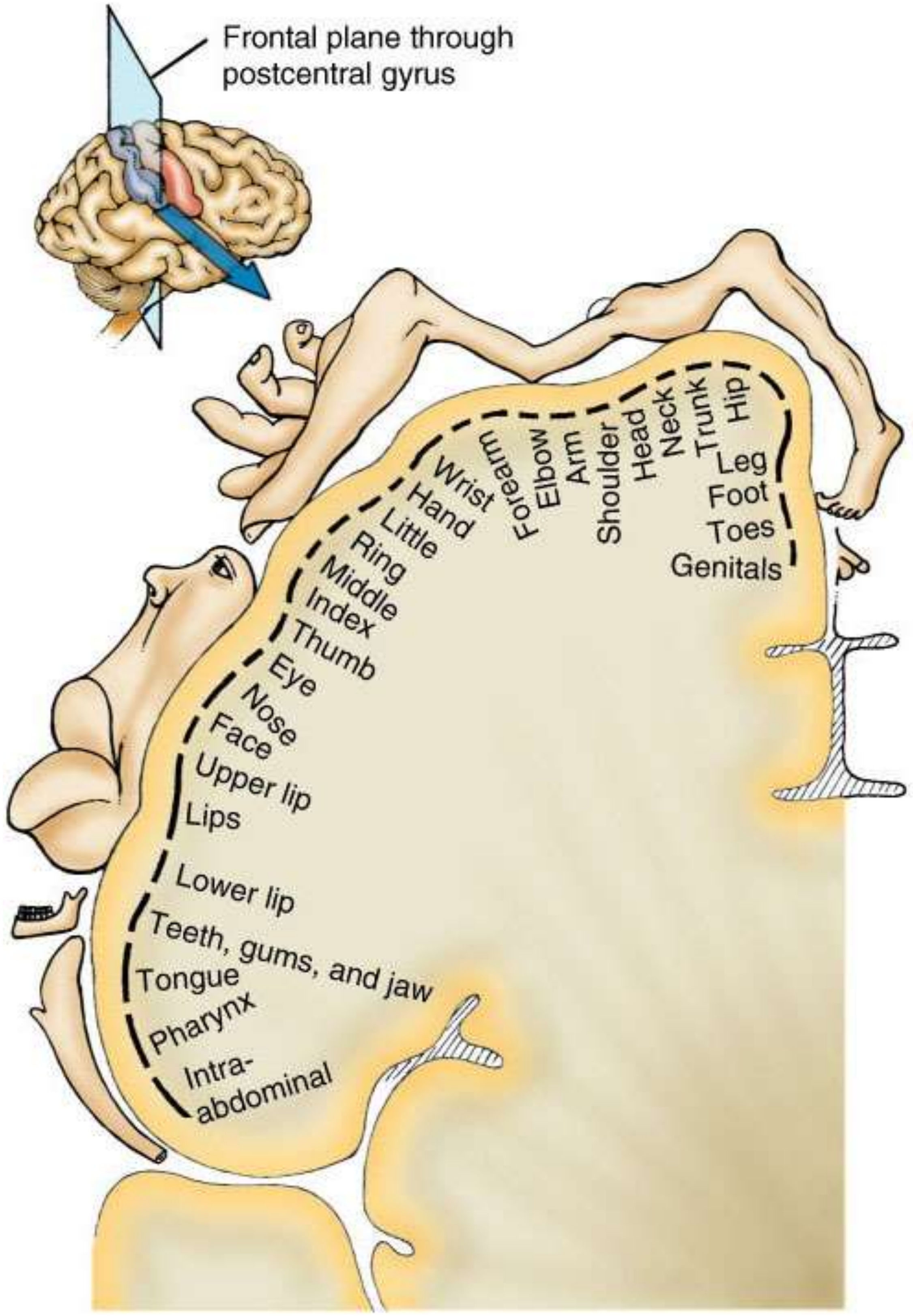
- Neurons that code **action-relevant properties** of objects
  - Neurons in the anterior intraparietal area (AIP), respond selectively to certain shapes (e.g. cylinder, sphere, cube), sizes and orientations.

- Neurons that code sensory information across **different modalities**
  - Neurons in the macaque premotor regions that respond to both the felt position of the arm and the visual position of the arm.

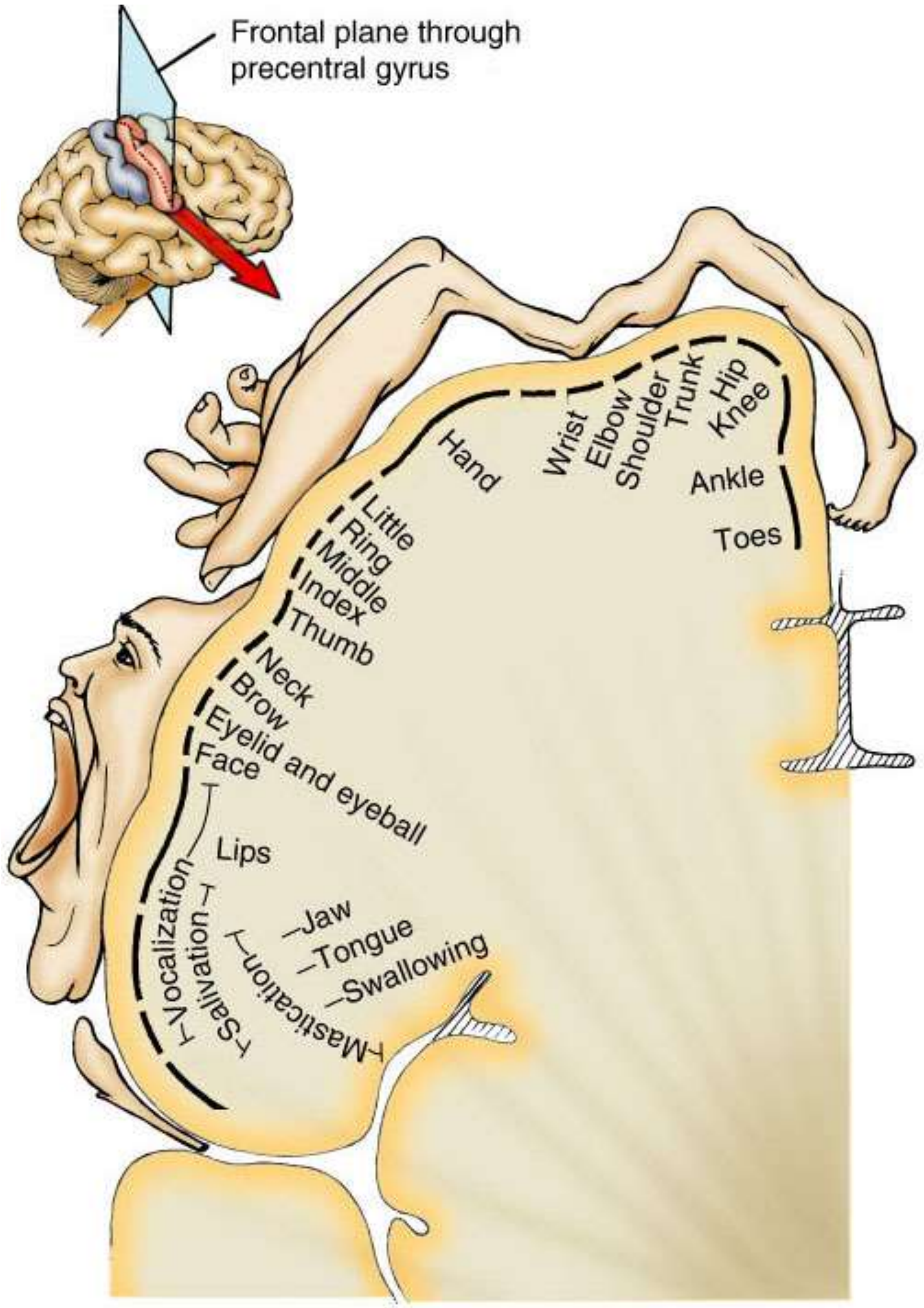
Tool use

- Tools, like other classes of object, are represented in the brain at several levels:
  - **A stored visual representation of the shape** of the object that is computed by the visual ventral stream.
  - **A semantic representation of the object** linked to medial and anterior temporal lobes.
  - **A volumetric representation of the tool** that has both visual and motoric components related to grasping. This may correspond to area AIP in the parietal lobes.
  - **A motor-based component that stores the conventional gestures associated with the tool.**

Somatotopy in primary motor and somatosensory cortex



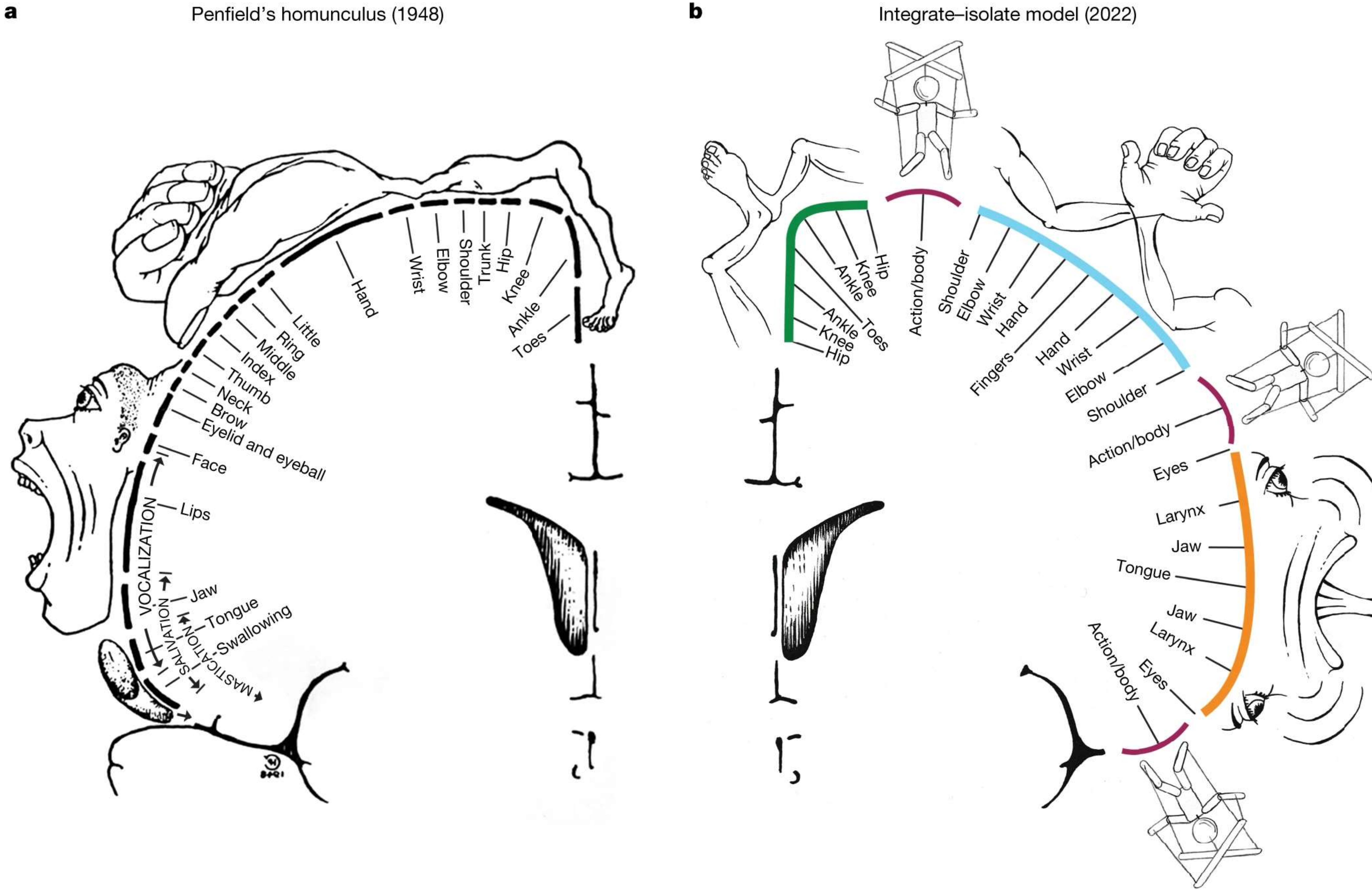
(a) Frontal section of primary somatosensory area in right cerebral hemisphere



(b) Frontal section of primary motor area in right cerebral hemisphere

- The M1 is responsible for execution of all **voluntary** movements of the body.
- The M1 communicate with the contralateral body
- The M1 is **somatotopically** organized.

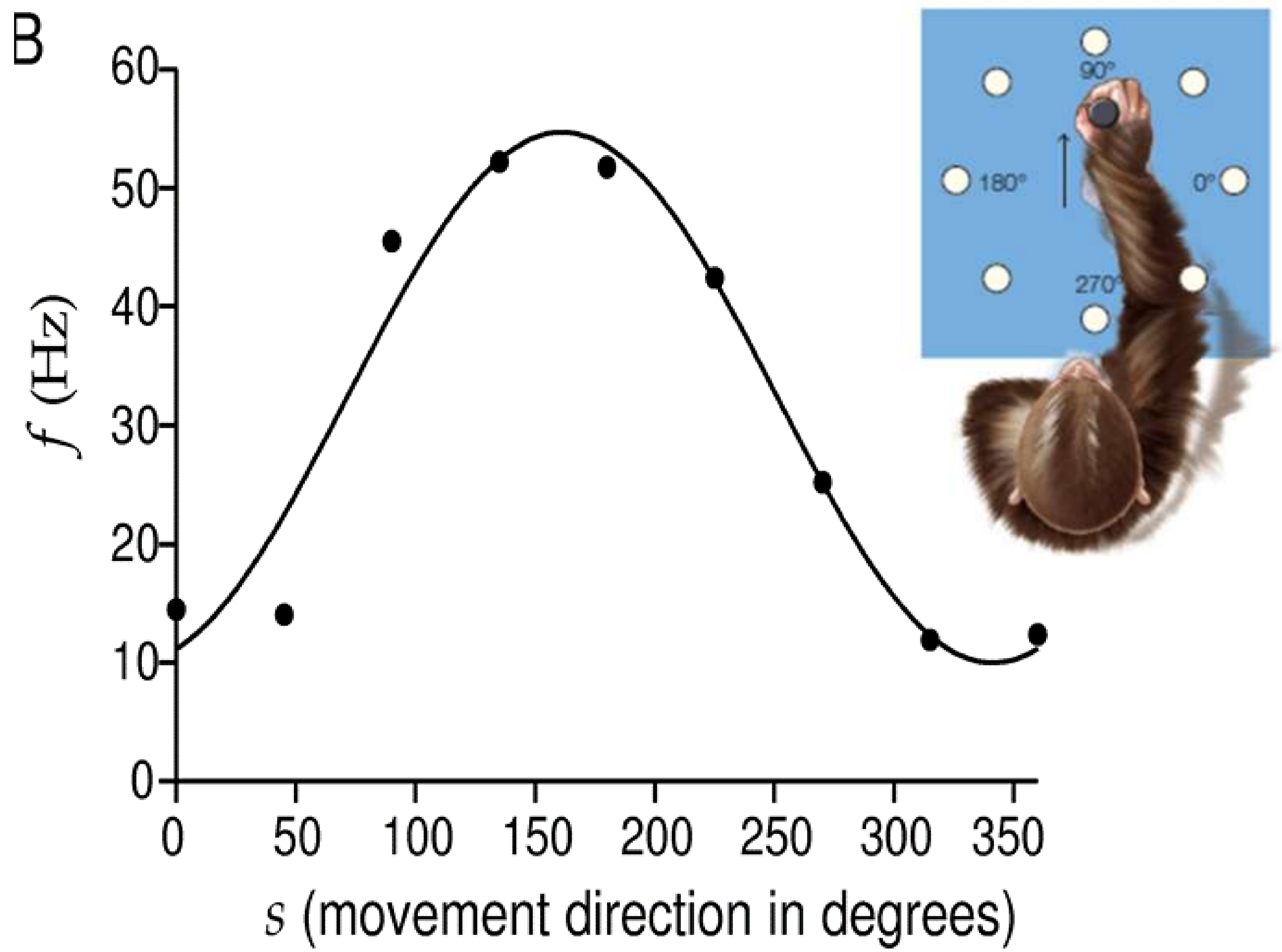
The interrupted homunculus, an integrate–isolate model of action and motor control.



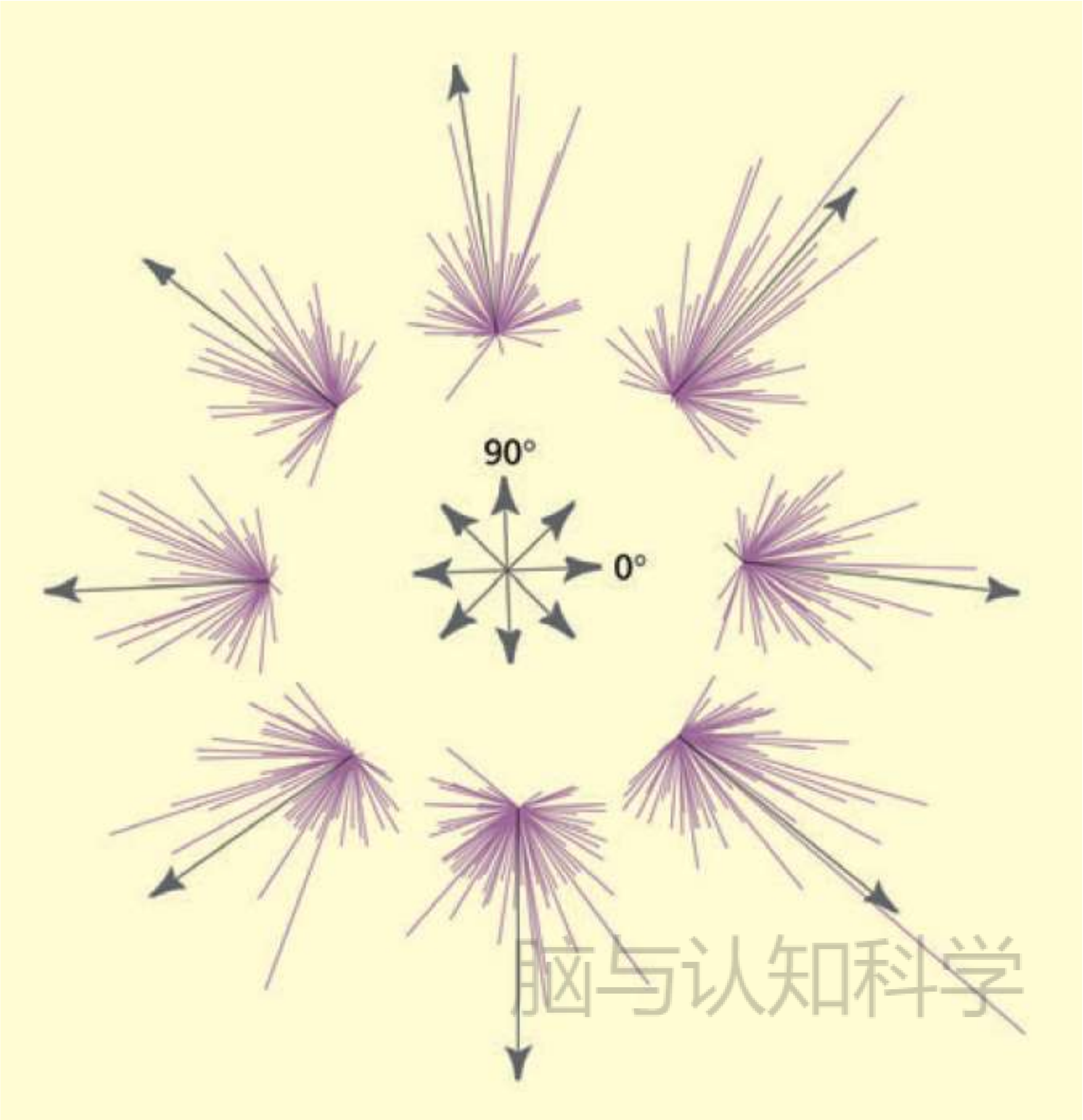
In the integrate–isolate model of M1 organization, effector-specific—foot (green), hand (cyan) and mouth (orange)—functional zones are represented by concentric rings with proximal body parts surrounding the relatively more isolatable distal ones (toes, fingers and tongue). Inter-effector regions (maroon) sit at the intersecting points of these fields, forming part of a somato-cognitive action network for integrative, allostatic whole-body control. As with Penfield's original drawing, this diagram is intended to illustrate organizational principles, and must not be over-interpreted as a precise map.

Population coding of movement direction

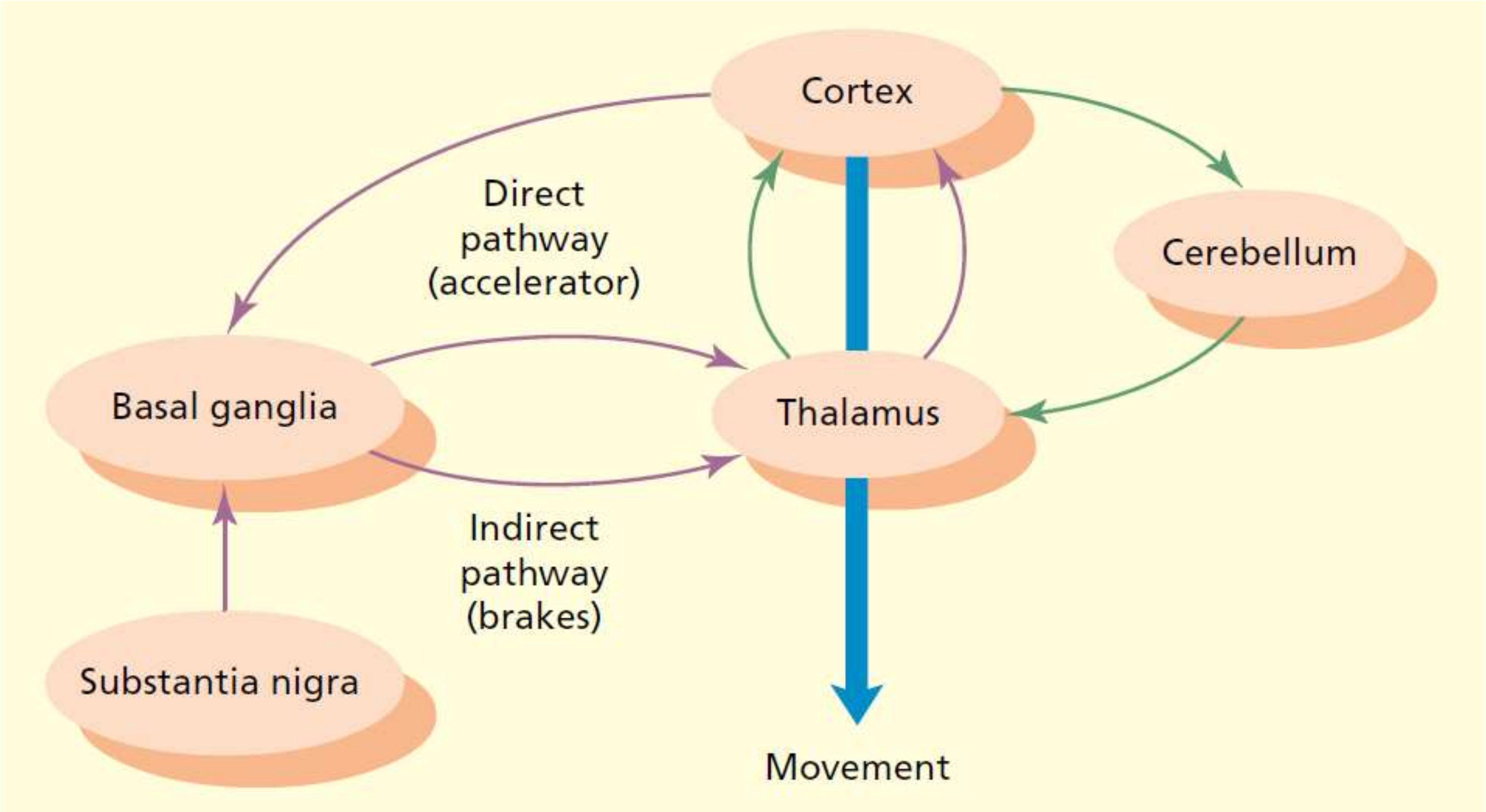
The firing of M1 neuron is related to the direction of movement rather than the spatial location of the endpoint.



The direction of the movement determined by a population of neurons.



Two main types of subcortical loop are involved in movement generation



- The cerebellar loop coordinates the timing and trajectory of movement using sensory and motor information.
- The basal ganglia motor circuit regulates the excitability of frontal motor structures and biases the likelihood of movement and the nature of the movement.

Hyperkinetic disorders(多动性障碍)

- Parkinson’s disease
  - Characterized by a lack of self-initiated movement.
  - The output of the indirect pathway (the brakes) is increased, the output on the direct pathway (the accelerator) is decreased.
- Huntington’s disease
  - Characterized by dance-like, flailing limbs (chorea) and contorted postures.
  - The output of the indirect pathway (the brakes) is reduced, whereas the output of the direct pathway (the accelerator) remains normal.
- Tourette’s syndrome
  - Characterized by excessive and repetitive actions such as motor tics or vocalizations.
  - The of the direct pathway (the accelerator) is increased, and the output prefrontal cortex tends to be more activate.

本章关键知识点

1. Two prominent subcortical structures involved in motor control are the cerebellum and the basal ganglia.
2. The motor system is hierarchically organized. Subcortical and cortical areas represent movement goals at various levels of abstraction.
3. The population vector is a representation based on combining the activity of many neurons.
4. The processes of action selection (what to do) and specification (how to do it) occur simultaneously within an interactive neural network that continuously evolves from planning to execution, with action selection emerging from a competitive process.
5. Mirror neurons respond to an action both when that action is produced by an animal itself and when the animal observes a similar action produced by another individual.

思考题

1、本体运动和识别其他人运动系统间的关系是什么？

2、本体动作网络和物体识别网络的功能联系是什么？

3、如何理解其他人的动作？

4、初级躯体运动和感知区的表征具有躯体拓扑表征，其他运动脑区是否也具有类似躯体拓扑映射？

5、如何为人工智能体添加类脑运动系统？

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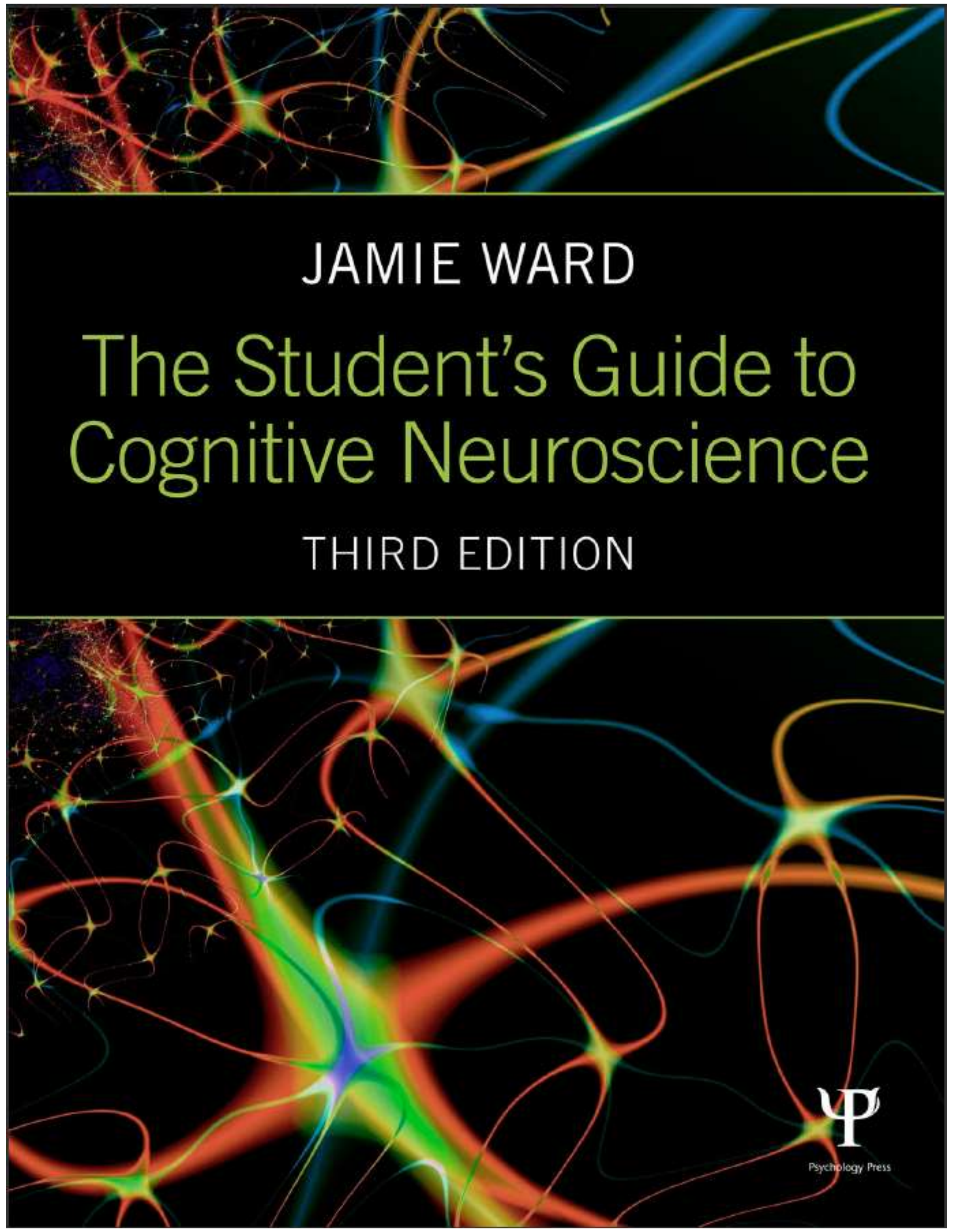
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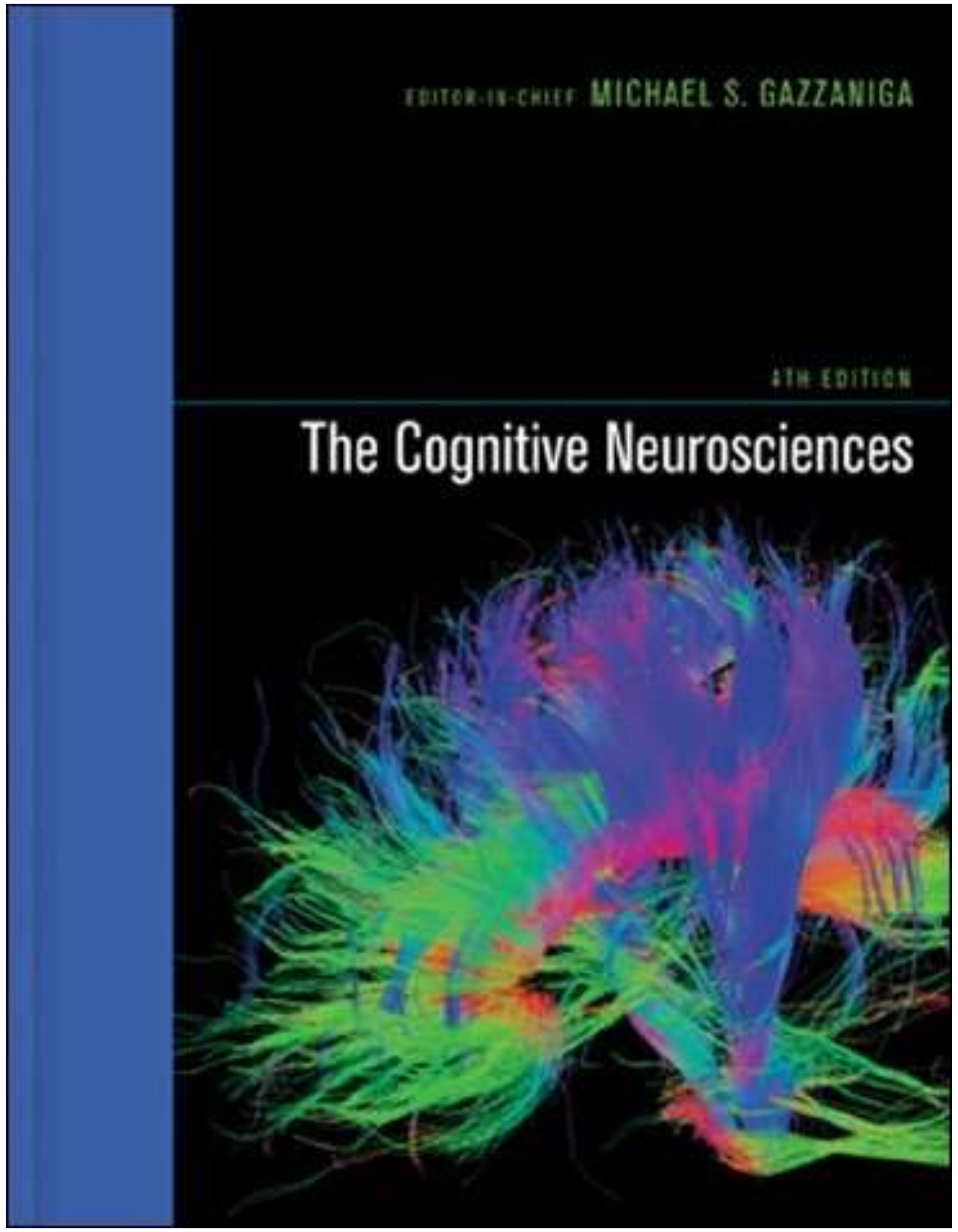
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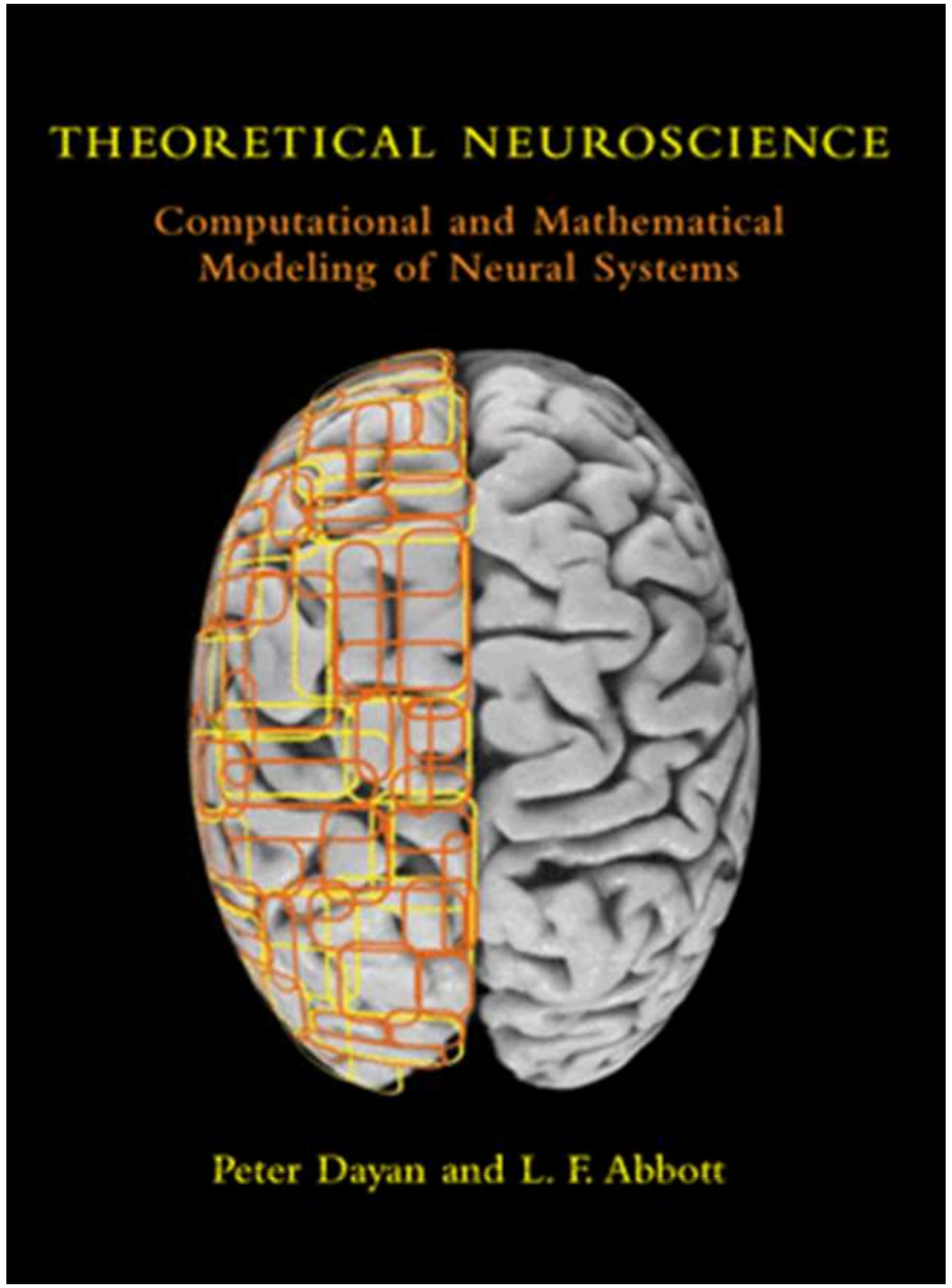
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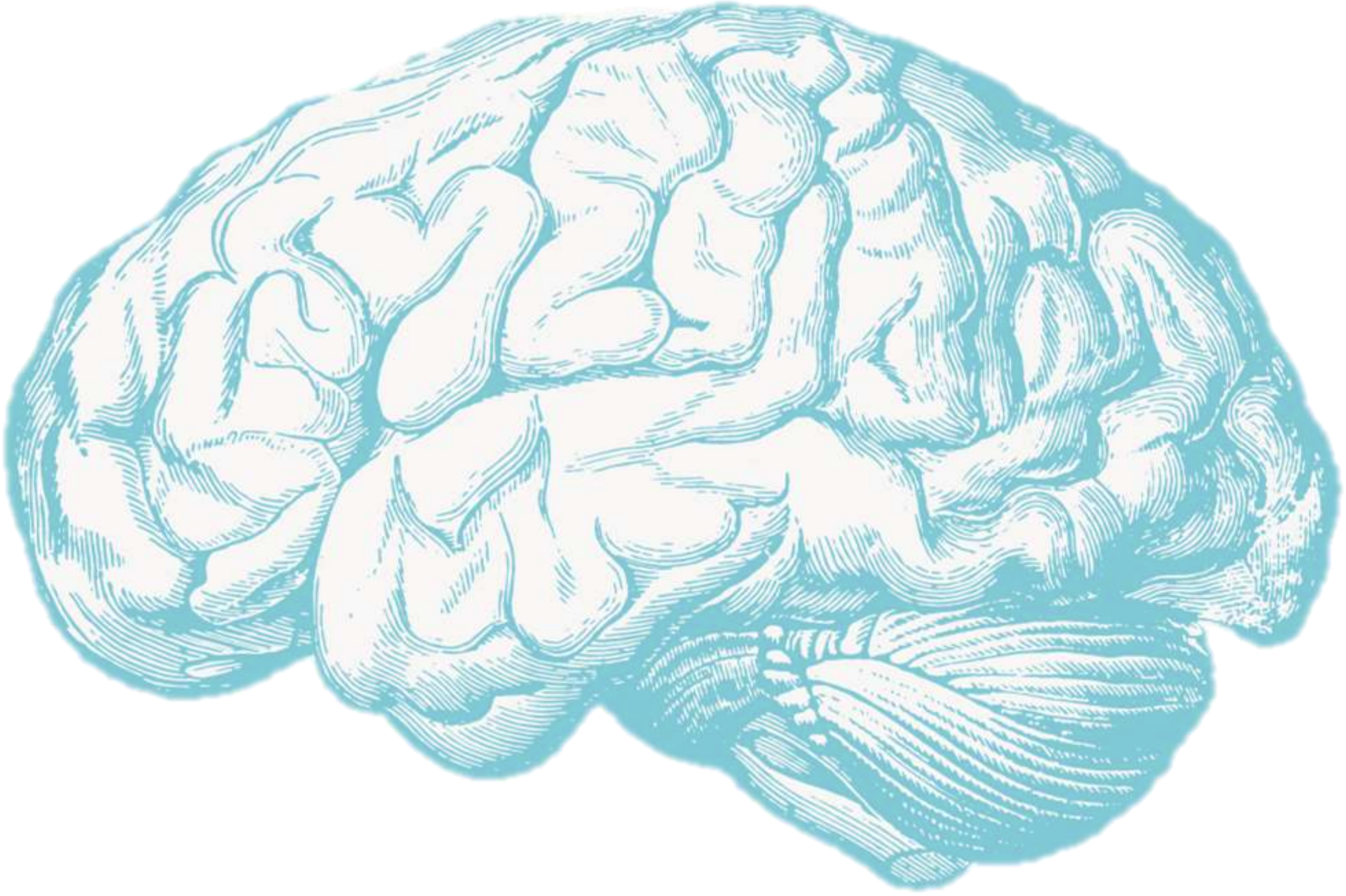

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脑与认知加工：语言

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