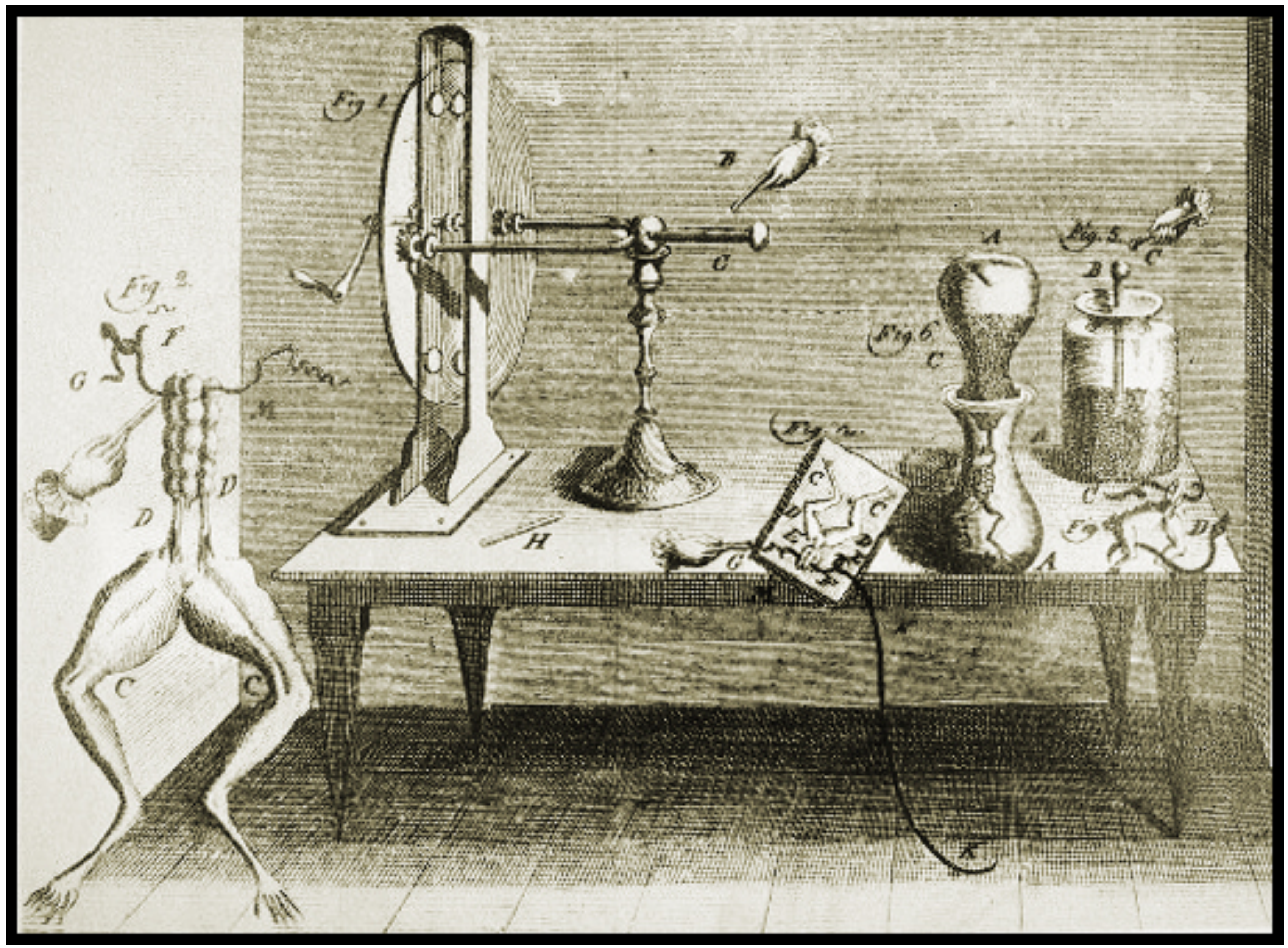
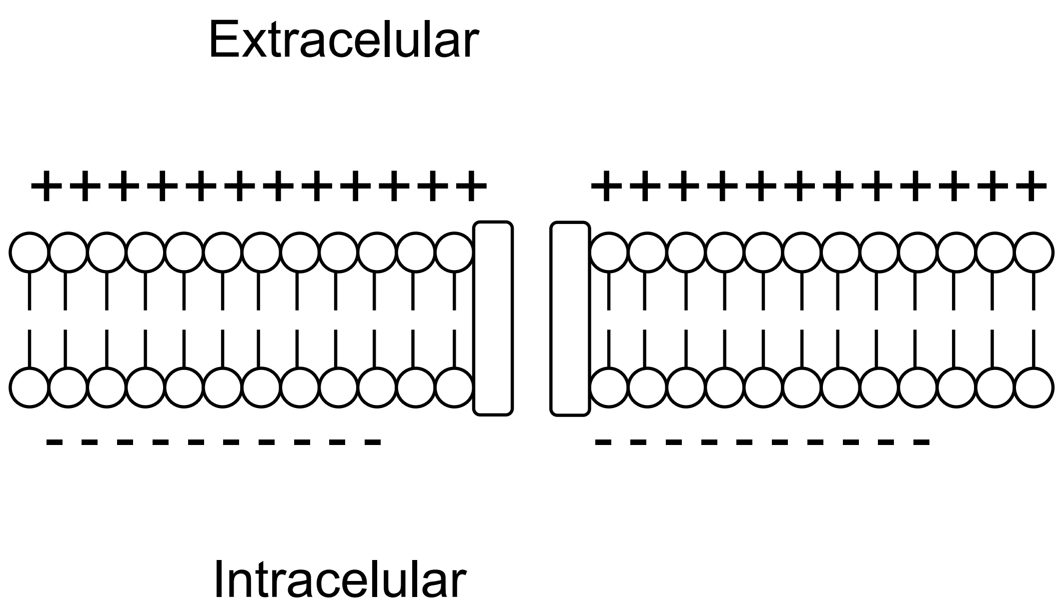
Señales electrofisiológicas

Los organismos vivos producen actividad eléctrica

Luigi Galvani
1737-1798



La neurona como circuito generador de corrientes



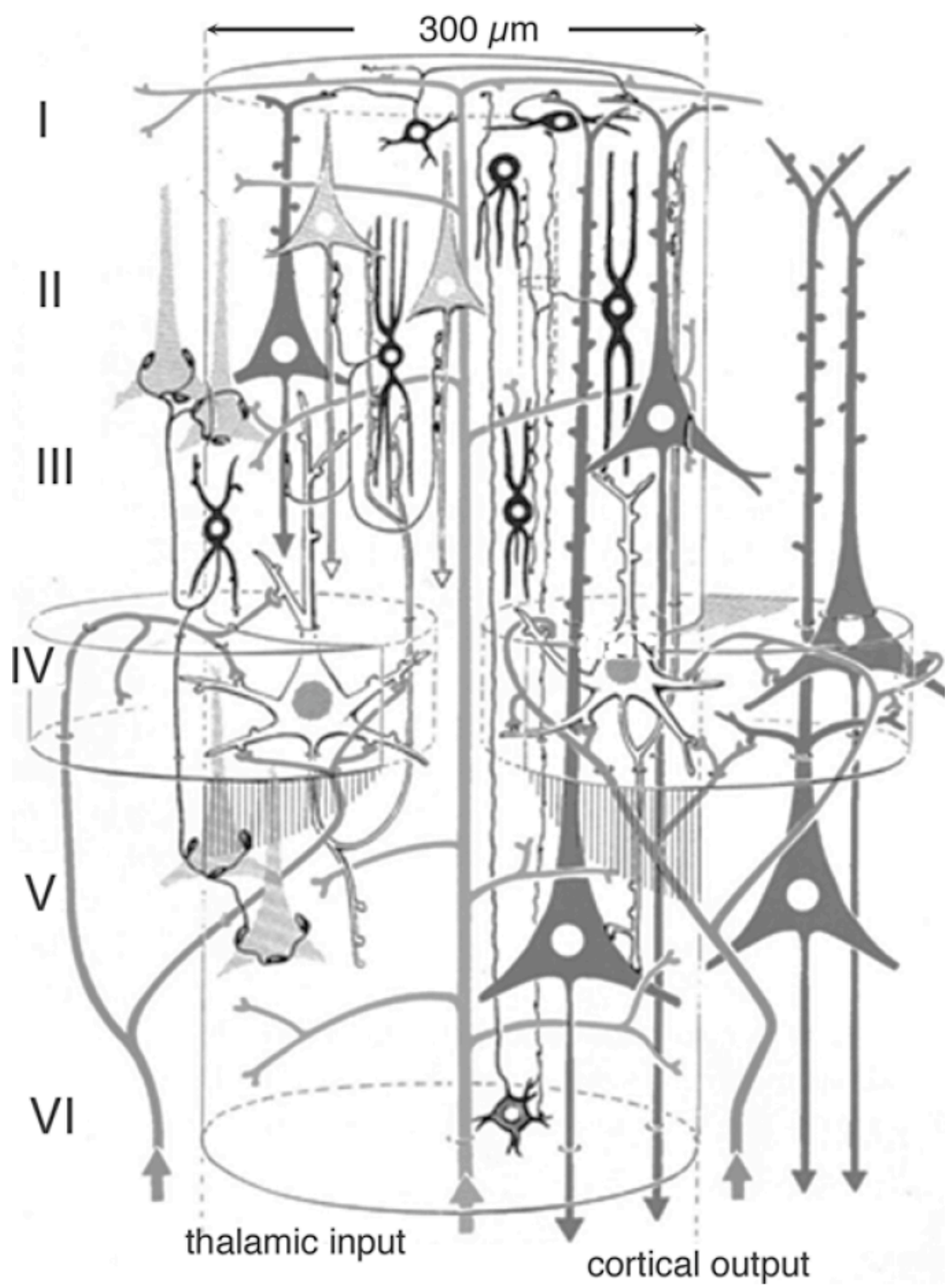
Resistencia = canales iónicos

Condensador = membrana plasmática

Resistencia (Ω) = distintos tipos de canales iónicos en la membrana de distintas células, con distintas velocidades de apertura y cierre.

Capacitancia (F) = dependiente del tamaño de la membrana de las distintas células.

Esquema simplificado de una columna cortical



Flujos de corriente en el axón y la dendrita

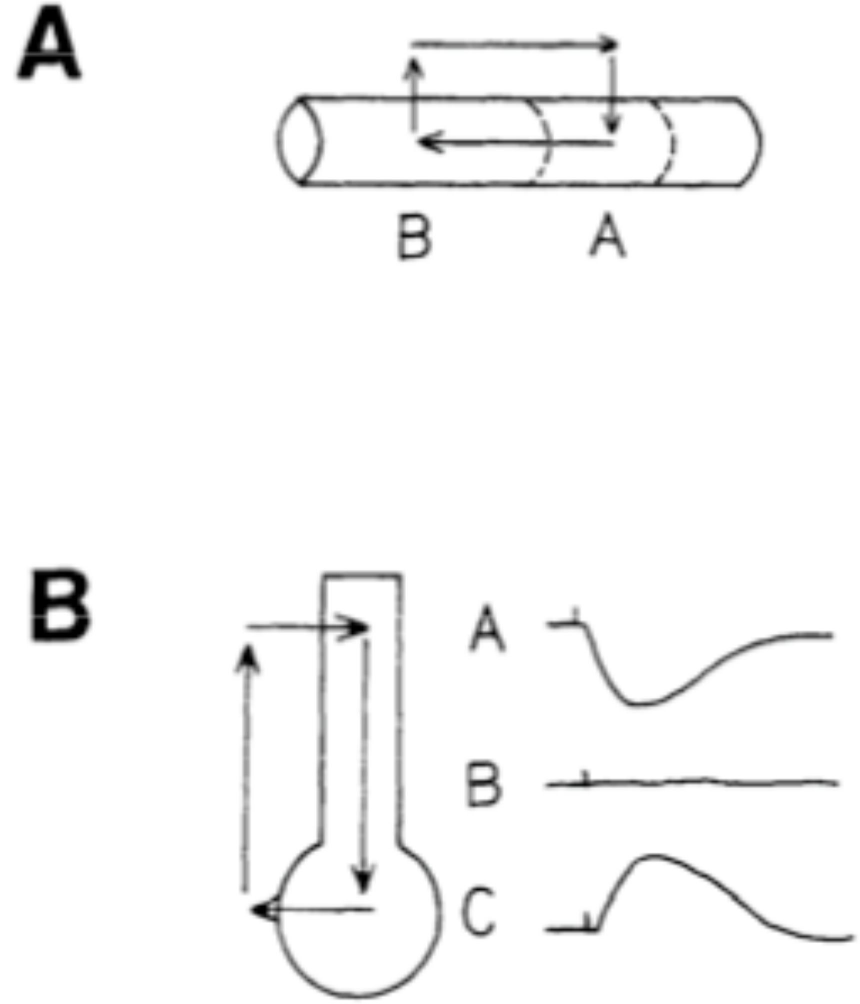
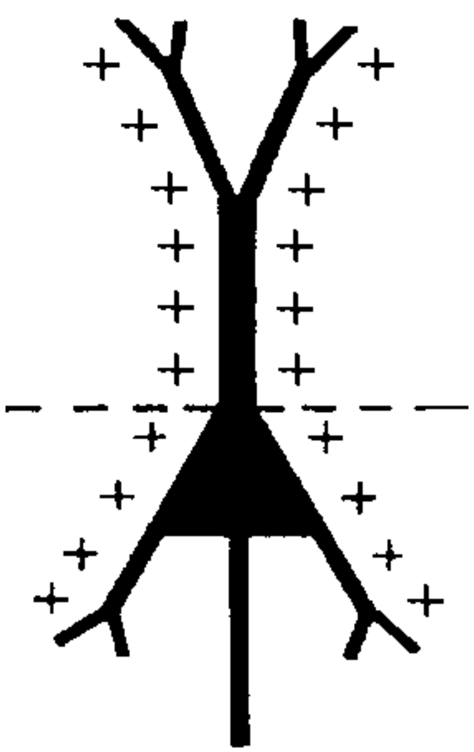
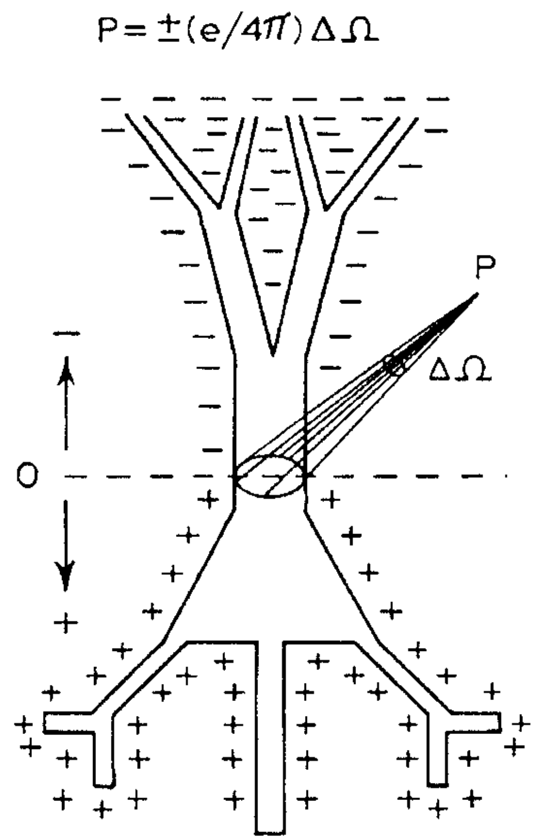
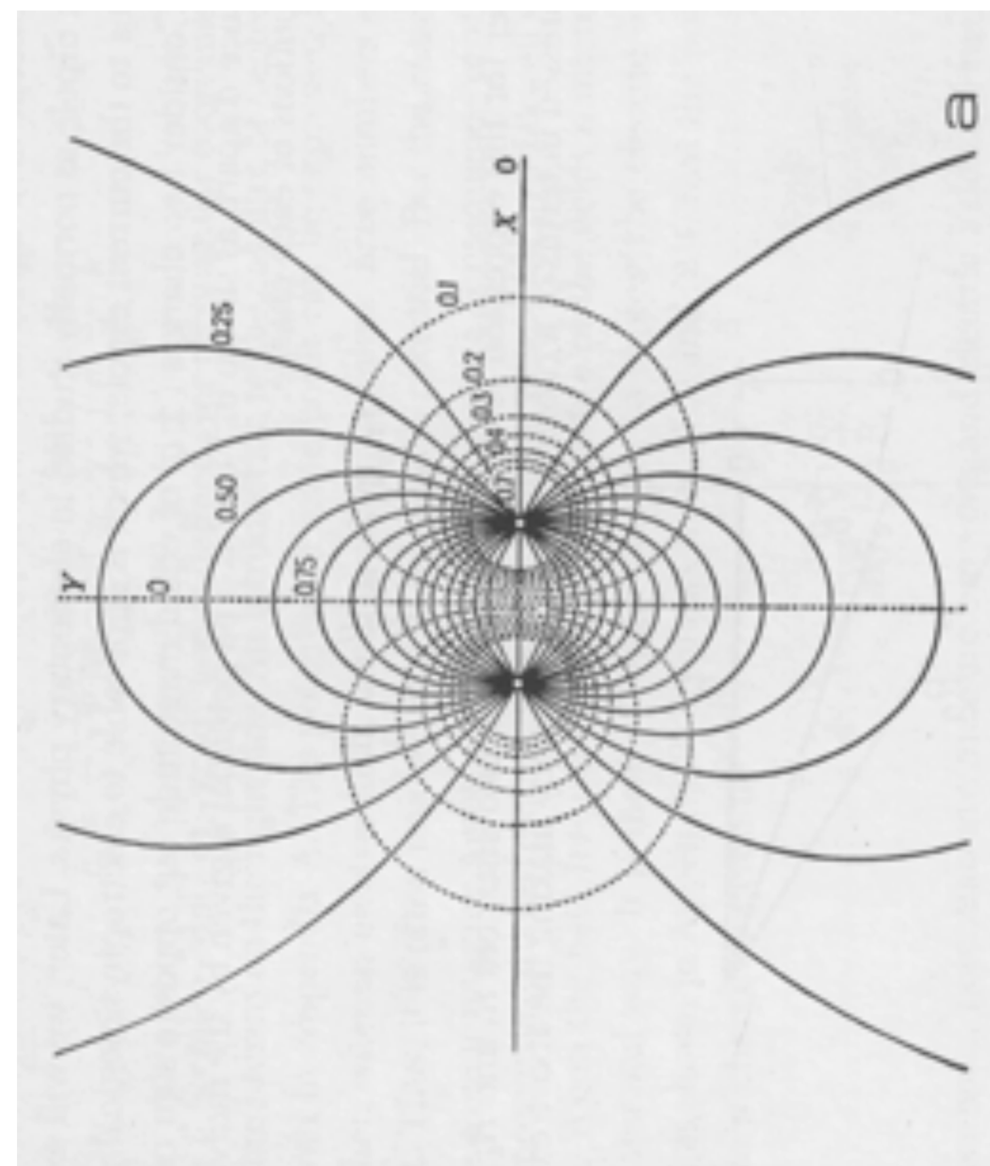


Fig. 1. (A) Current flows in a closed loop when an action potential begins at point A (with inward sodium currents). Passive currents exit at point B. (B) Synaptic excitation at the distal dendrites drives a current loop that flows from positive (point C) to negative potentials (point A) in the extracellular medium. Response transients, positive upward.

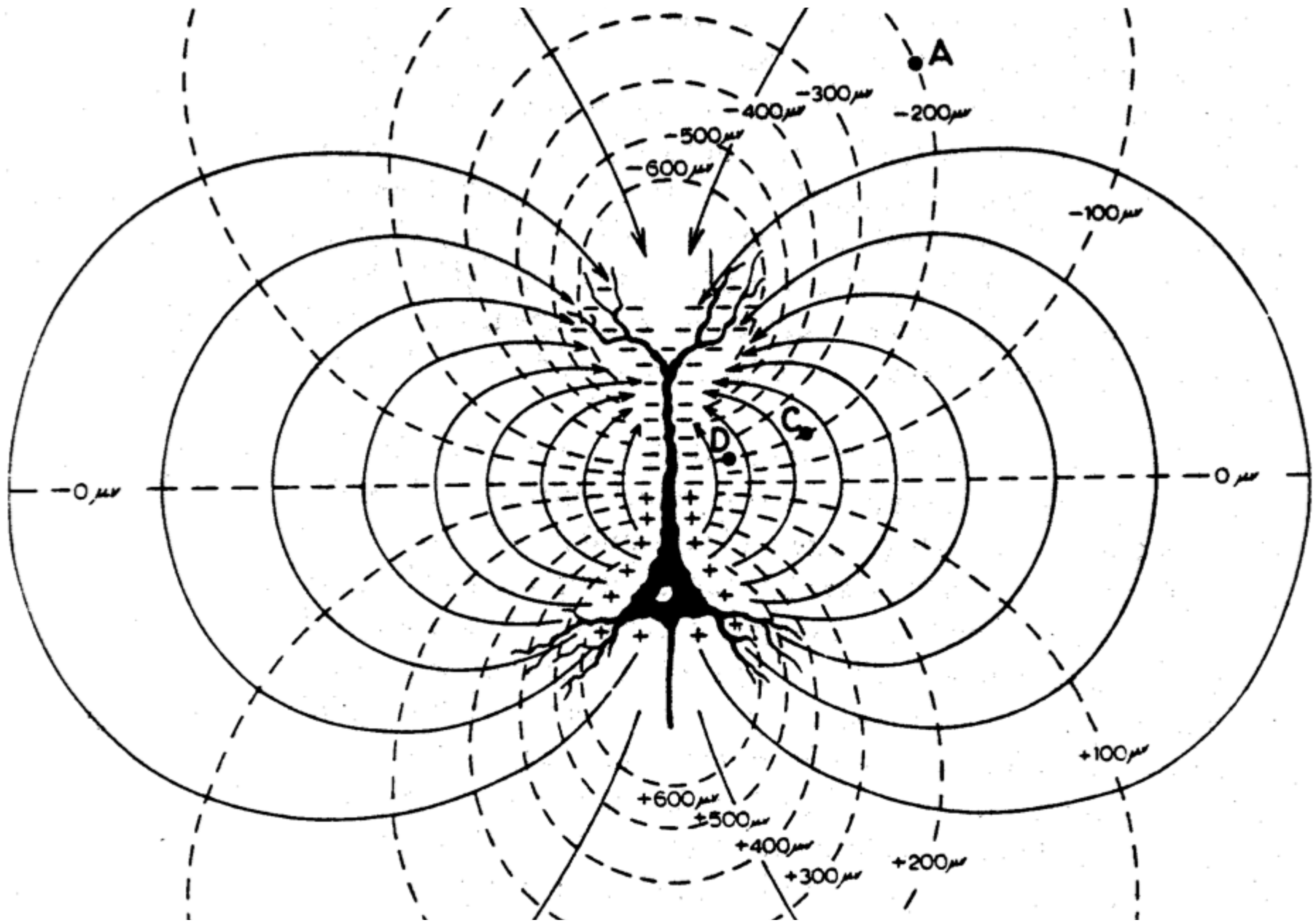
Principio de la generación de corrientes extracelulares en el tejido cerebral







Principio de generación del LFP



El modelo del campo generado depende del tipo de neurona y de la configuración espacial

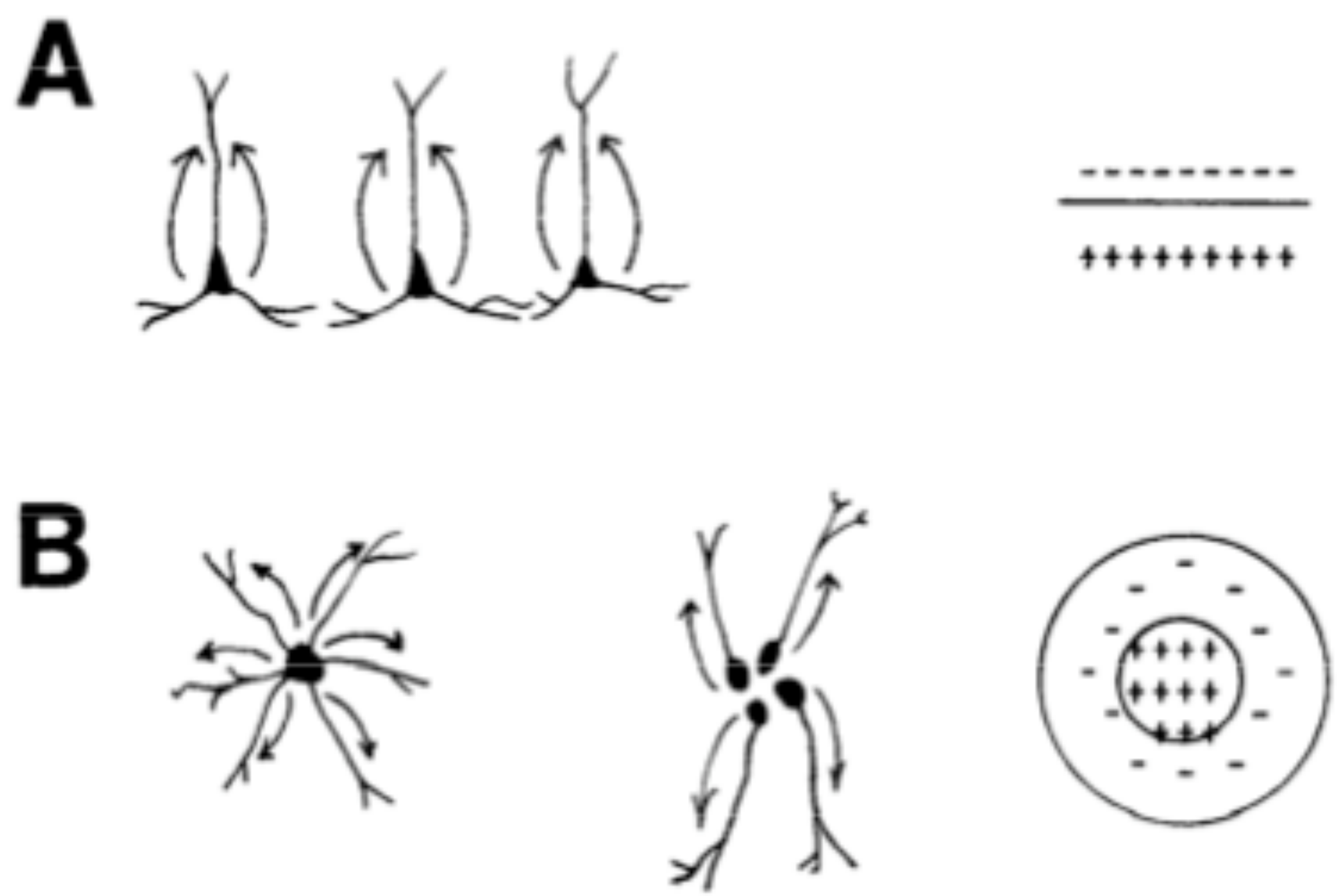
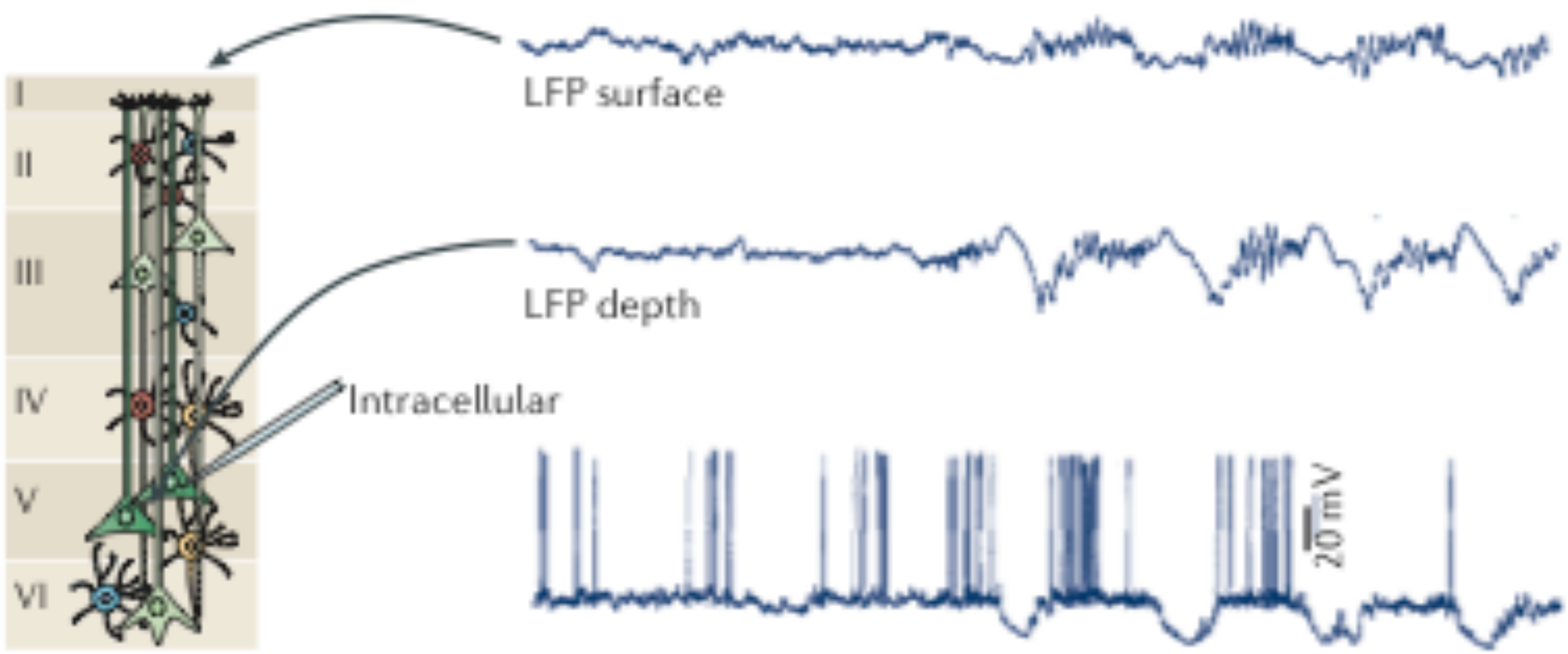
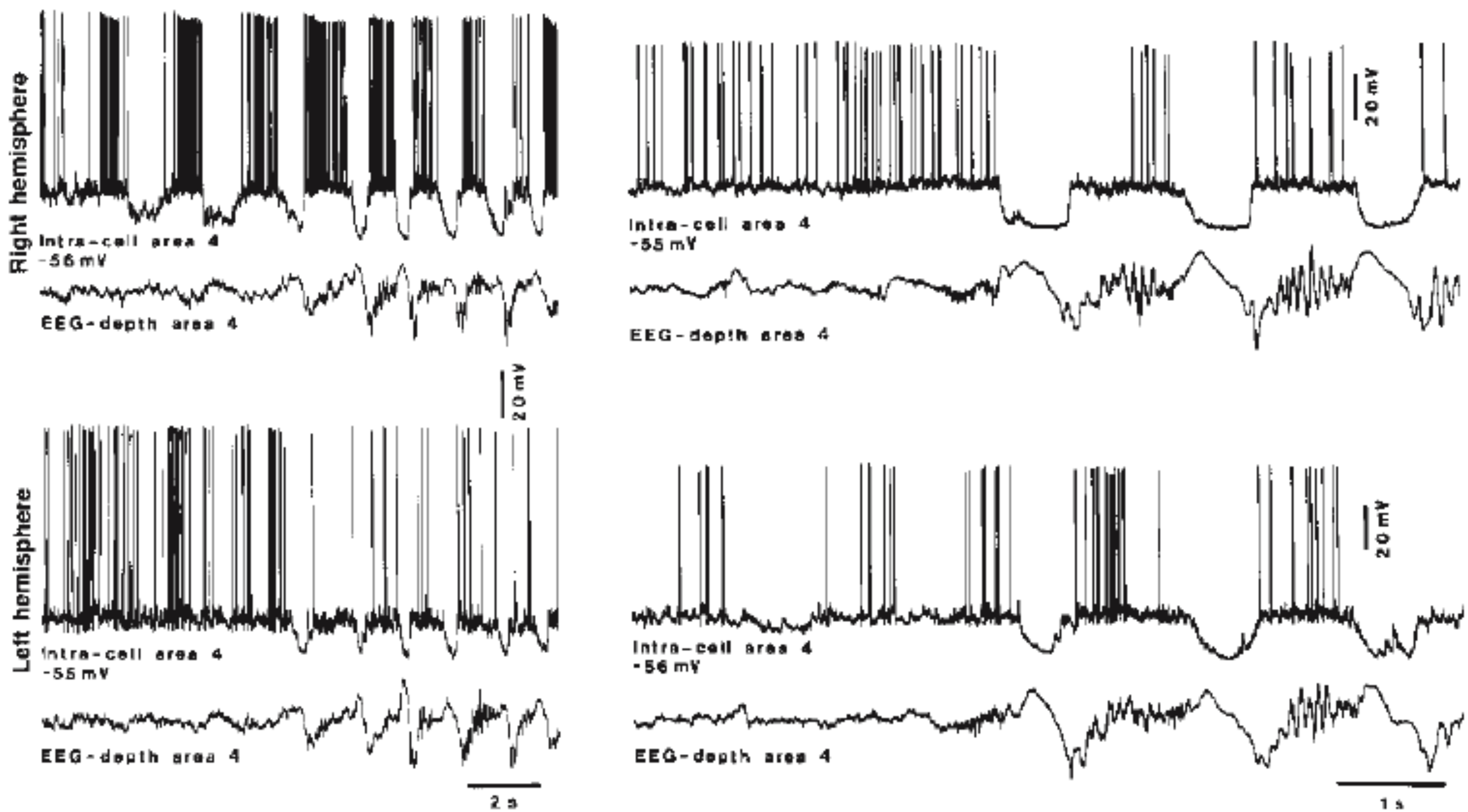


Fig. 3. (A) Excitation of the distal apical dendrites of pyramidal cells gives rise to mainly axial currents; the electrostatic model is a dipole layer that gives an open field. (B) Excitation of the distal dendrites of a single stellate cell or excitation of the periperal dendrites of cells in a nuclear structure gives rise to radial currents; the electrostatic model is one of concentric layers of charges that generate a closed field.

Registro del LFP con diferentes técnicas



El EEG representa la suma del potencial de membrana de neuronas sincrónicamente oscilantes



La diferencia de potencial genera una corriente extracelular que se propaga en el espacio, según el principio de "la fuente y el resumidero", y que es la base de la conducción volumétrica en el tejido cerebral.

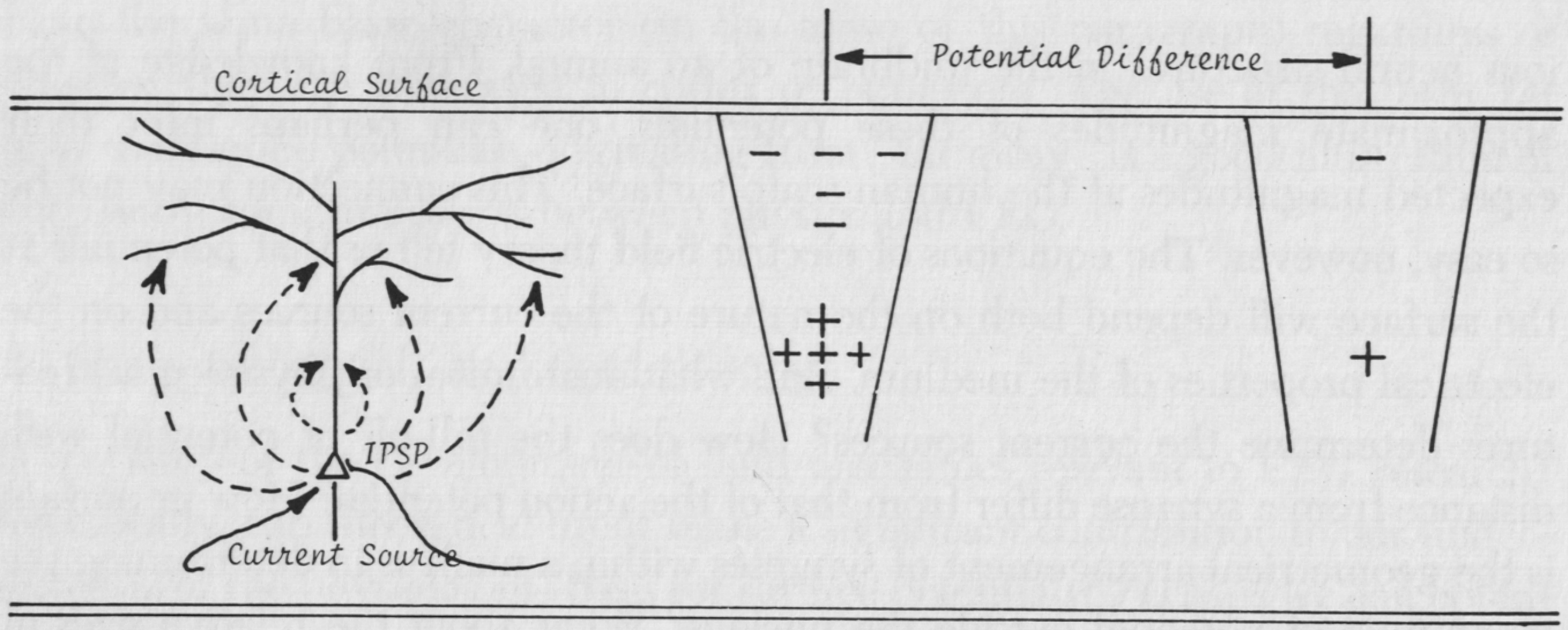


Fig. 1-7. Current source near the cell body due to an inhibitory postsynaptic potential (IPSP) causes potential difference between two cortical surface locations.

La configuración eléctrica que predomina en la corteza correponde a un dipolo de capa

Medición del Potencial eléctrico: aplicación del concepto del ángulo sólido.

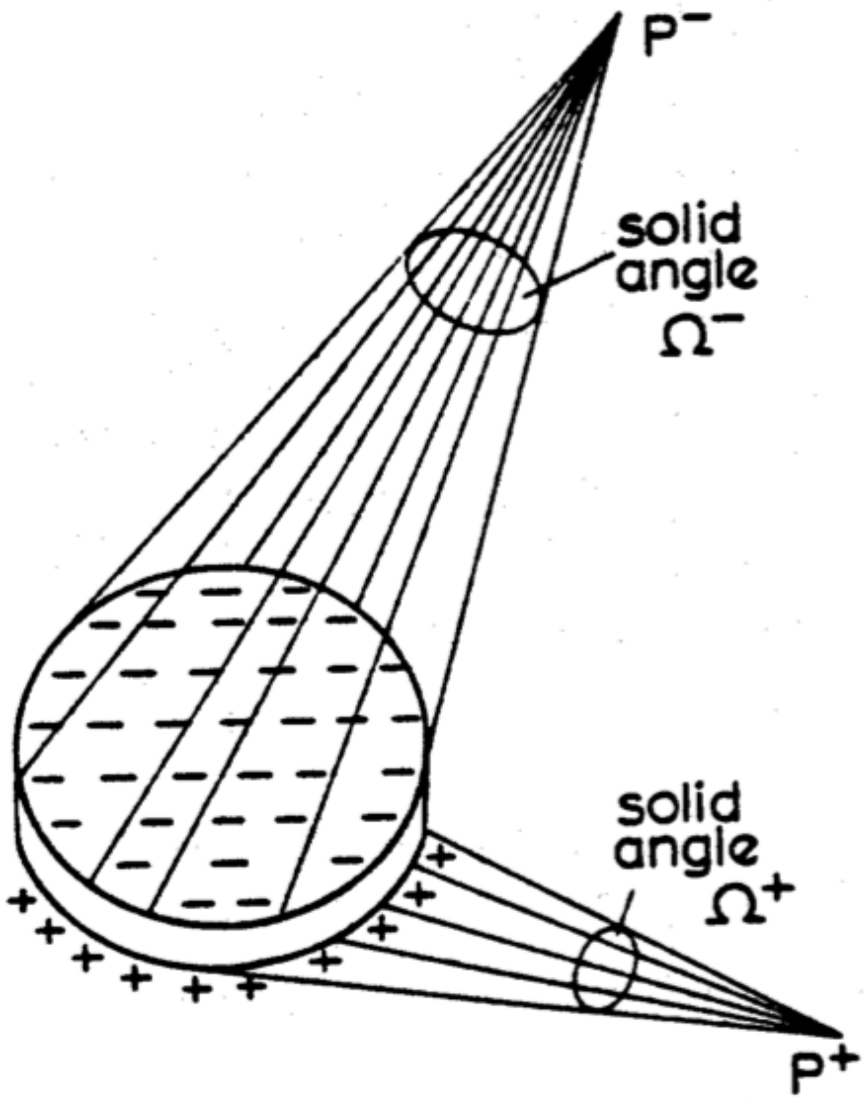


FIG. 2. Schematic representation of the solid angle principle of volume construction: in an infinite homogeneous medium the potential measured at point P^- is proportional to the solid angle Ω^- subtended at P^- by the negative, or at point P^+ to the solid angle Ω^+ subtended at P^+ by the positive surface of the disk-shaped dipole layer. At all points facing the negative side of the dipole layer, the sign of the potential is negative, and at all points facing its positive side, it is positive.

Medición del Potencial eléctrico: aplicación del concepto del ángulo sólido.

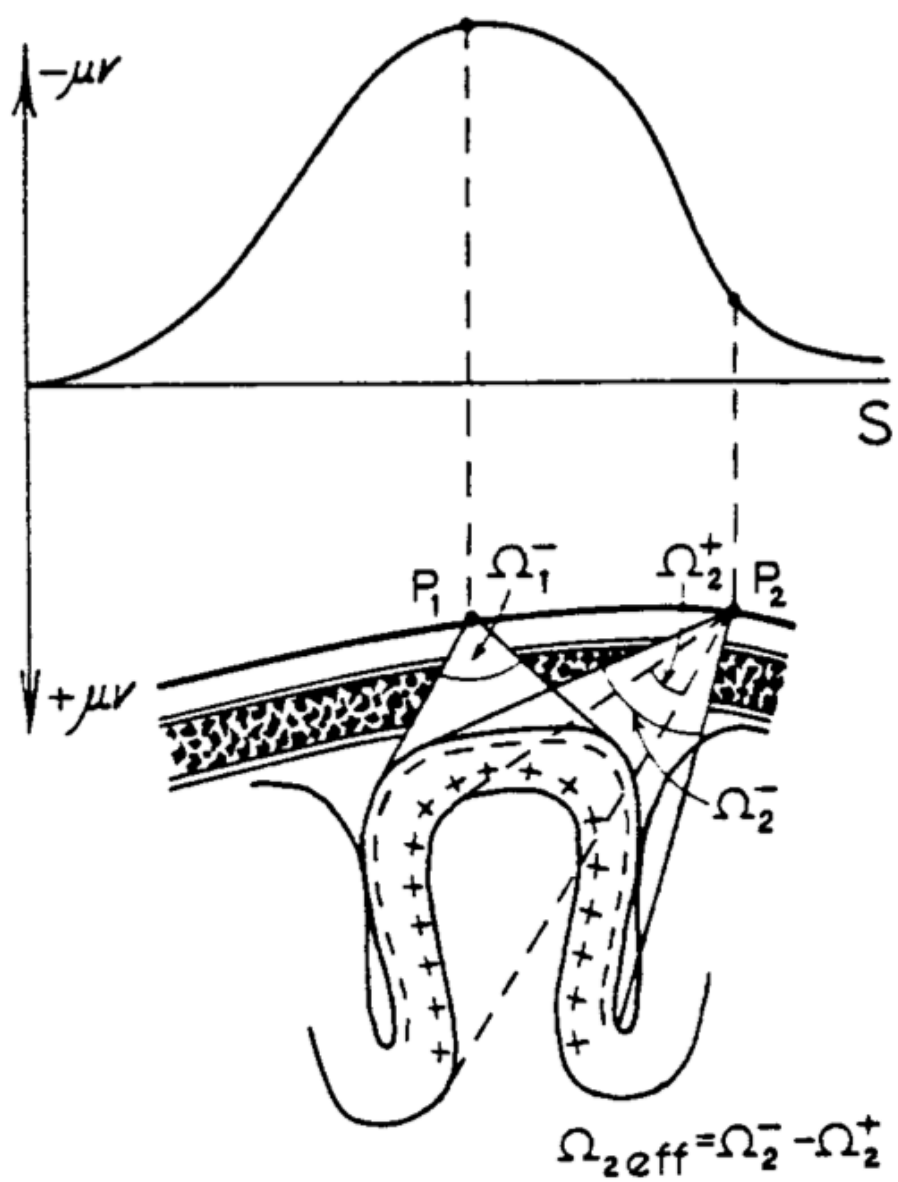
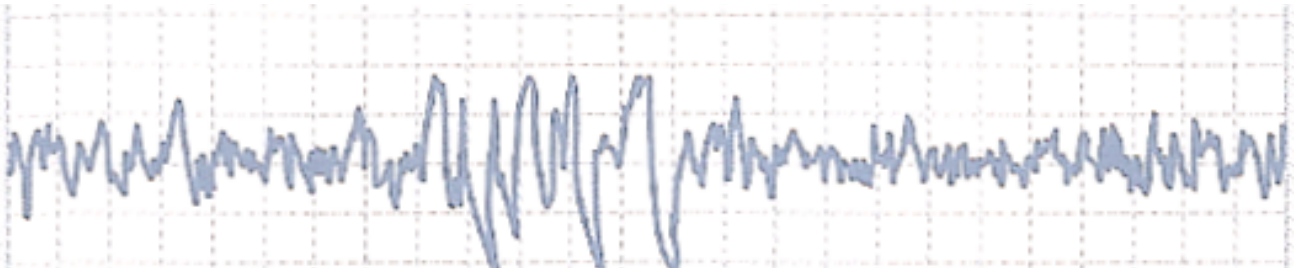
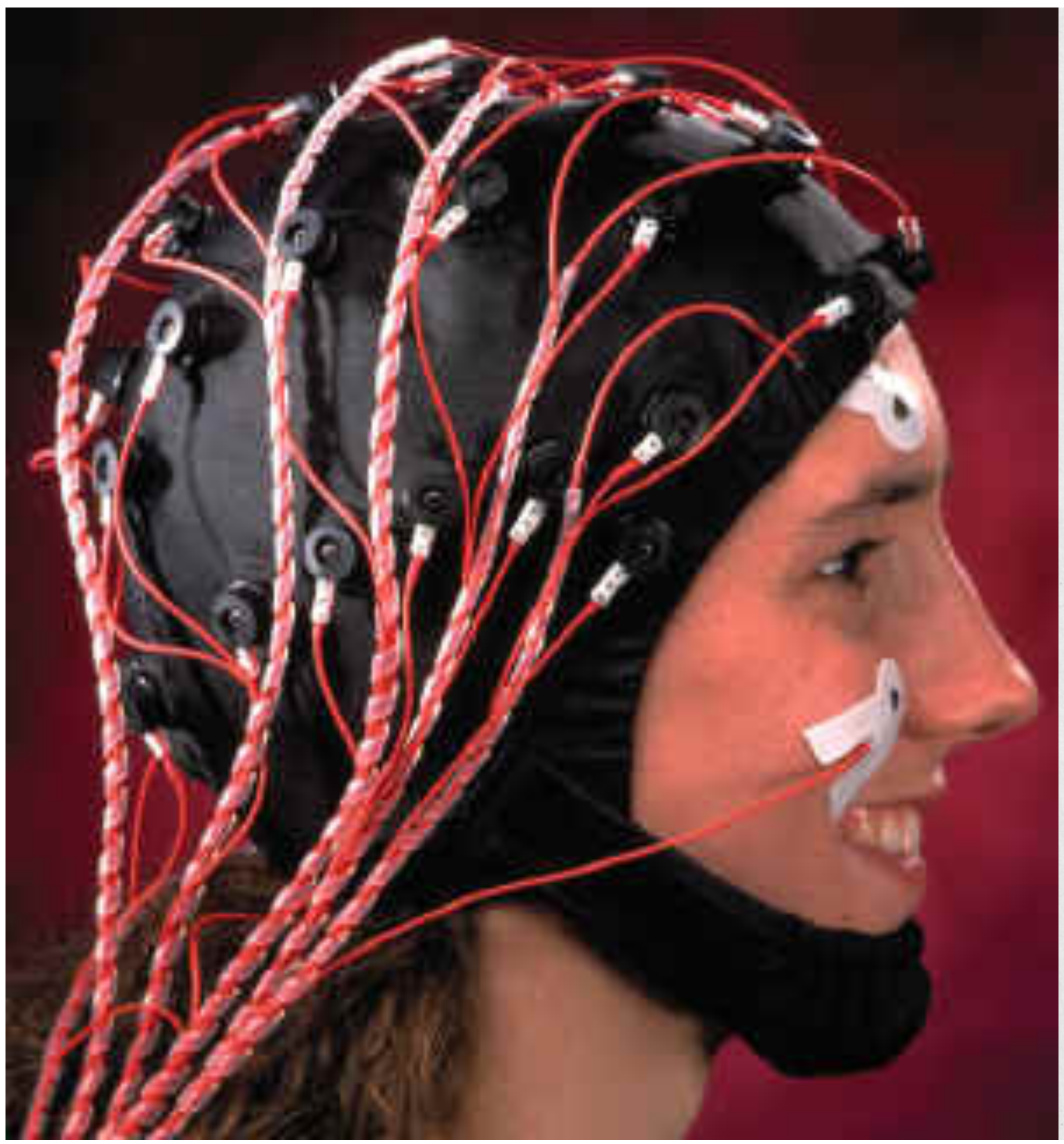
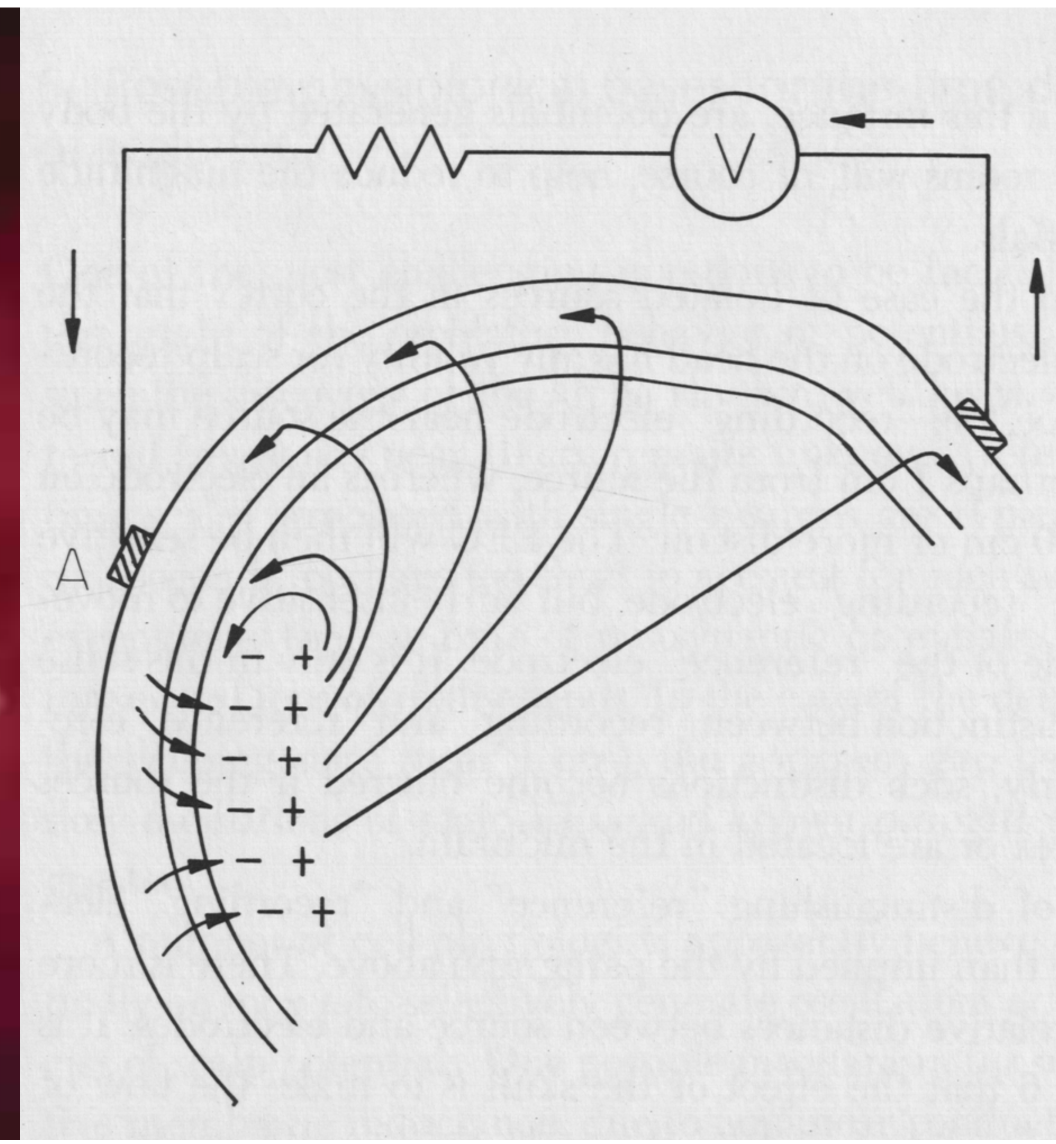


FIG. 7. Potential distribution along line S on the scalp created by the synchronous activation of a curved portion of cortex that occupies the crown of a gyrus and its two sides forming the proximal walls of the two adjacent sulci. At P1, the potential depends only on the solid angle Ω_1^-, since at this point an electrode "sees" only a portion of the negative side of the dipole layer. At P2, an electrode "sees" the negative side of the portion of the dipole layer occupying the crown of the gyrus and the wall of the proximal sulcus under the angle Ω_2^-; however, it also "sees" under the smaller angle Ω_2^+ the positive side of the portion of the dipole layer located in the wall of the distal sulcus. The potential at P2 is therefore smaller than would be expected if only Ω_2^- were the angle determining the size of the potential at P2 and is proportional to the effective solid angle Ω_{eff}, which equals the difference between Ω_2^- and Ω_2^+, the polarity being negative, since $\Omega_2^- > \Omega_2^+$. As is the case for a flat area of cortex oriented in parallel to the scalp the potential profile is bell-shaped. (Taken in part from Gloor, 1975.)



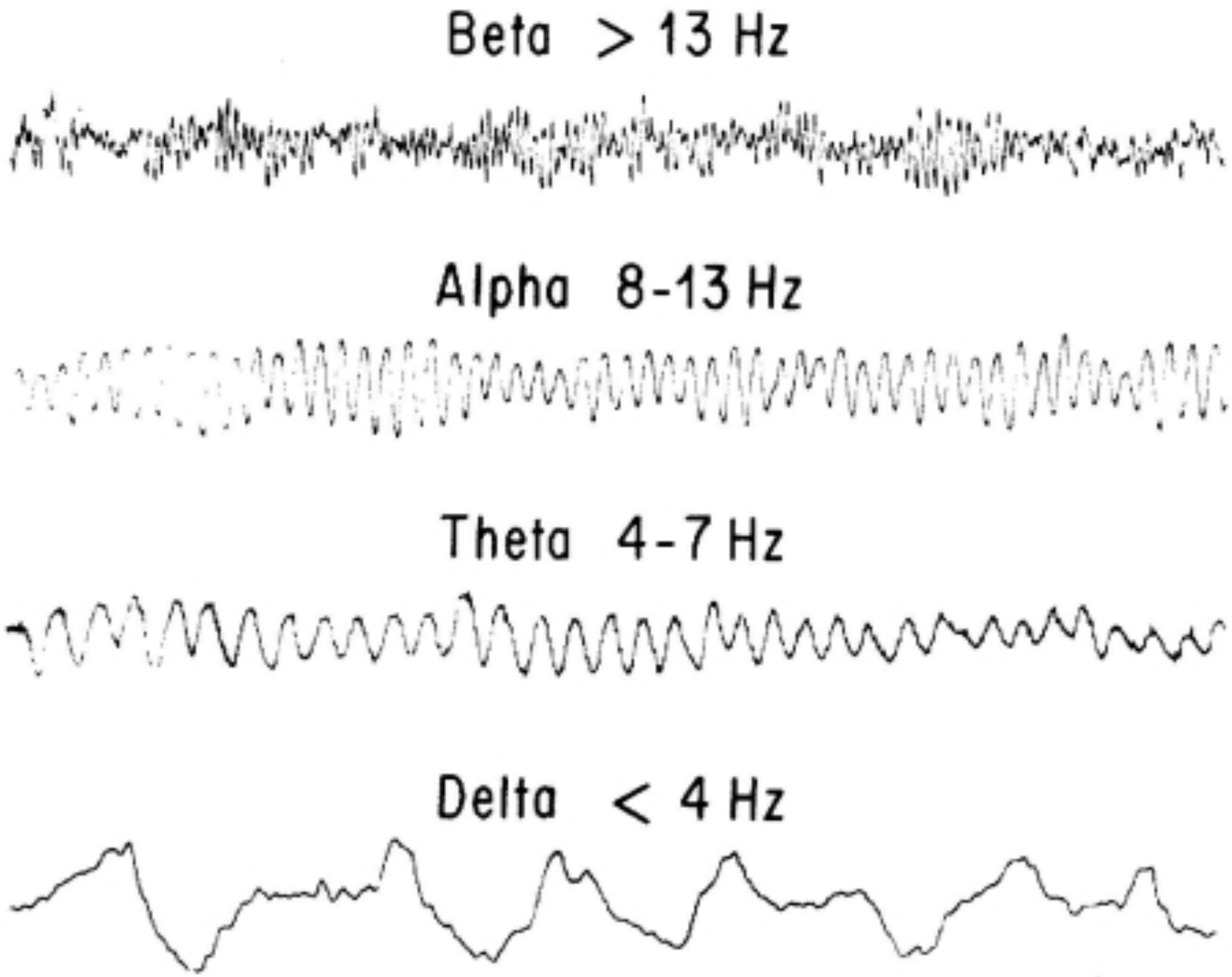
$$\Phi(\vec{r}) = \frac{1}{4\pi\epsilon_0} \sum_{i=1}^{n} \frac{q_i}{R_i}$$



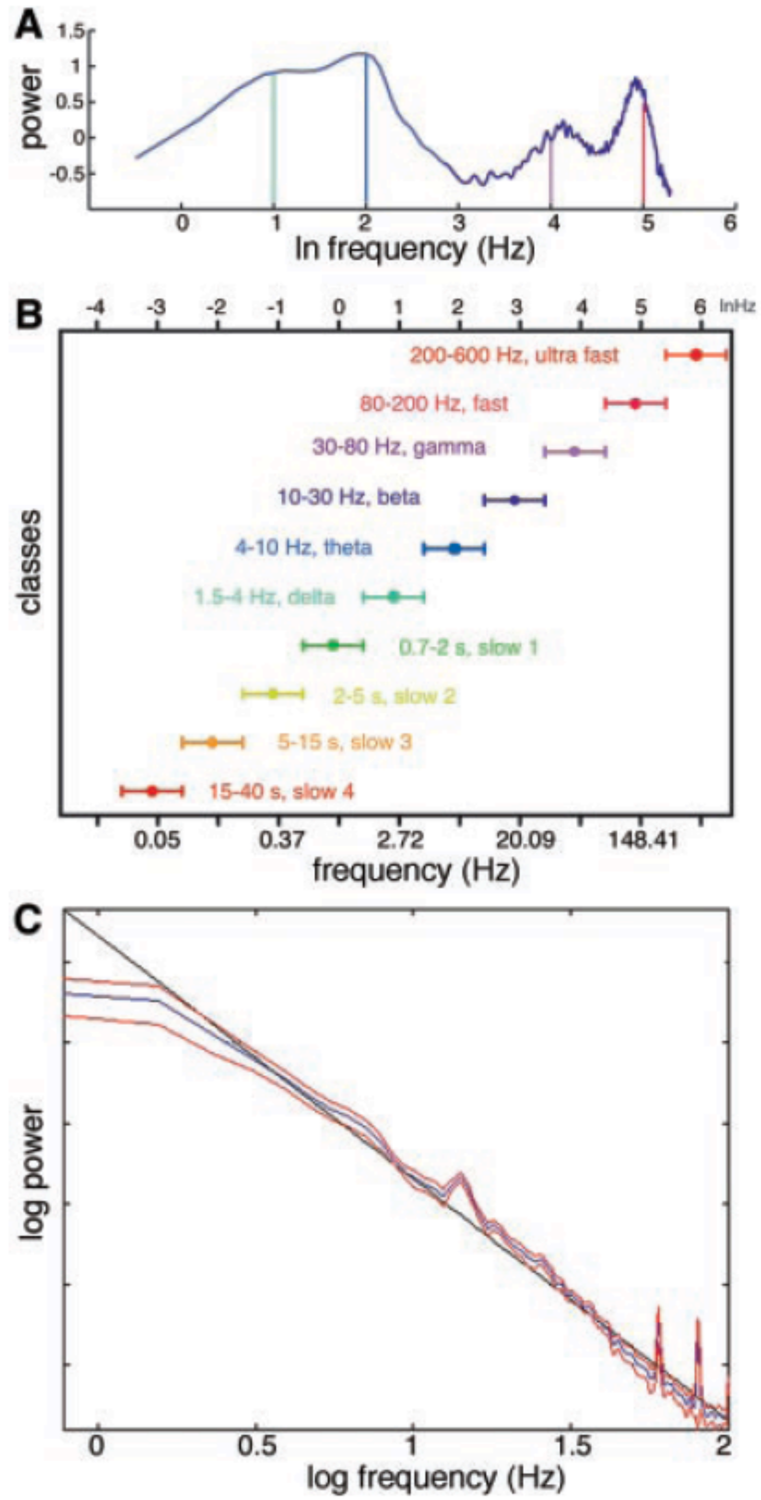


Registro de EEG

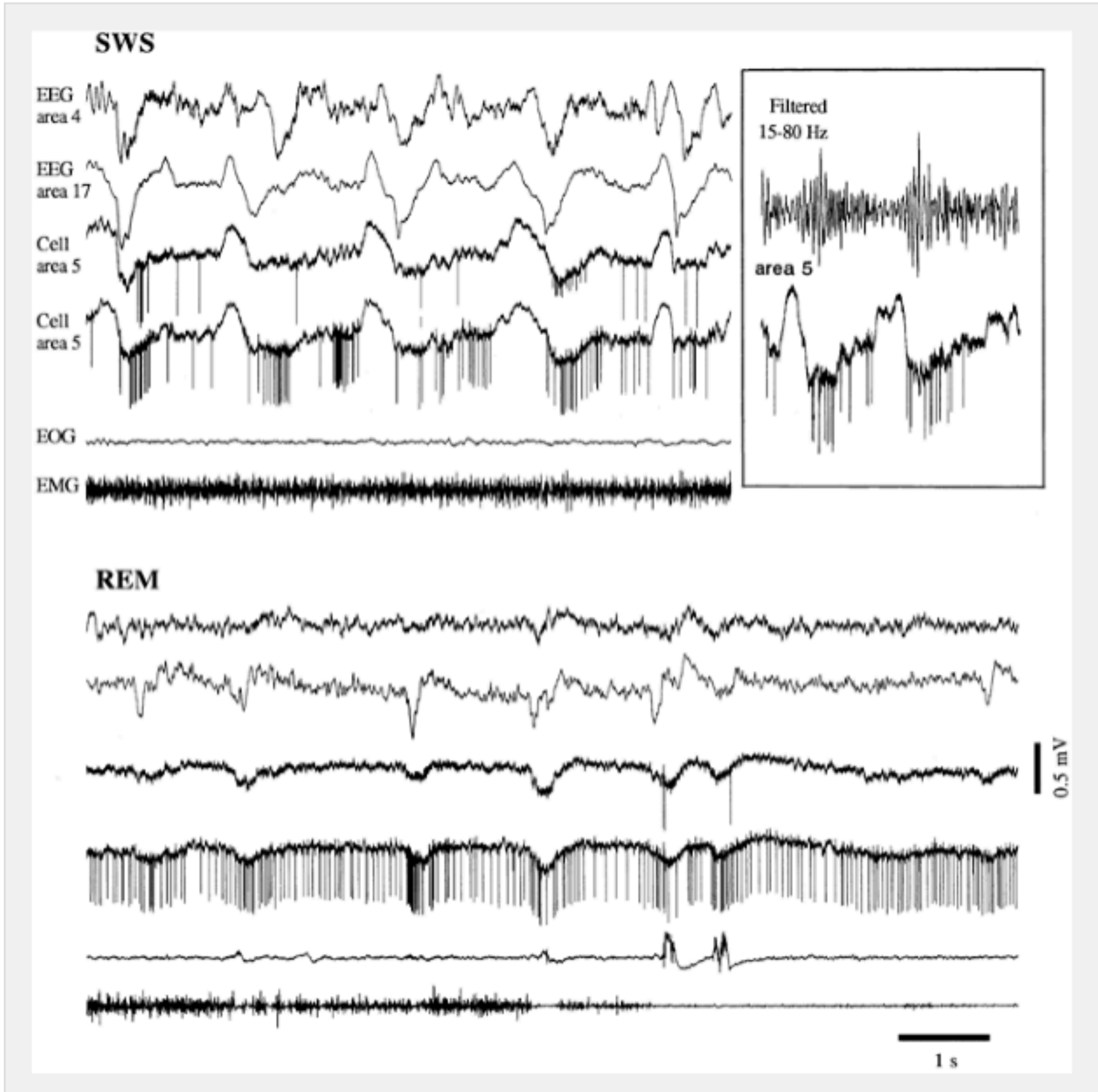
Existen distintas bandas de frecuencia



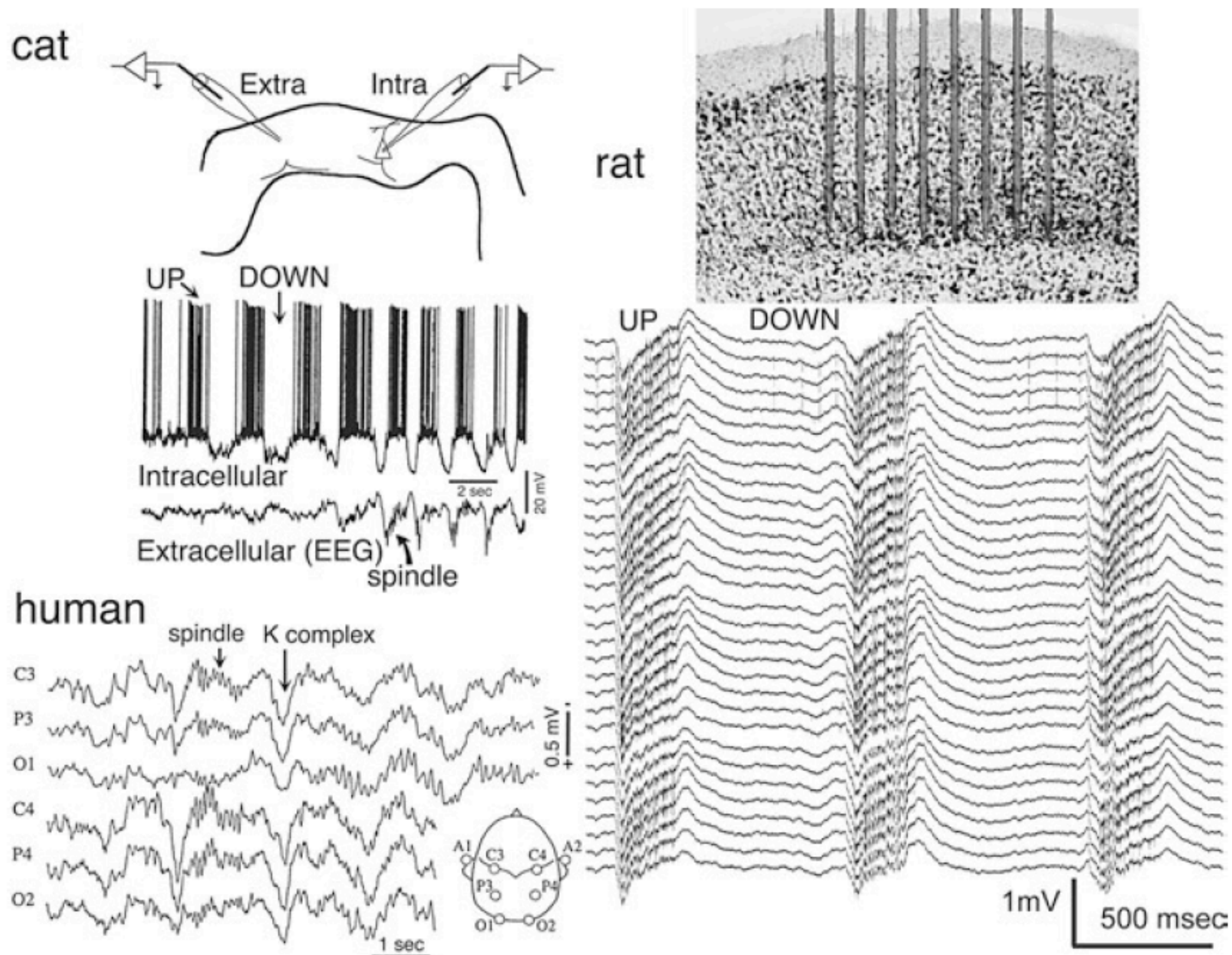
Escala temporal de los ritmos cerebrales



Los ritmos cerebrales definen macroscópicamente el estado cerebral



Las neuronas oscilan entre estados de alta y baja probabilidad de excitabilidad



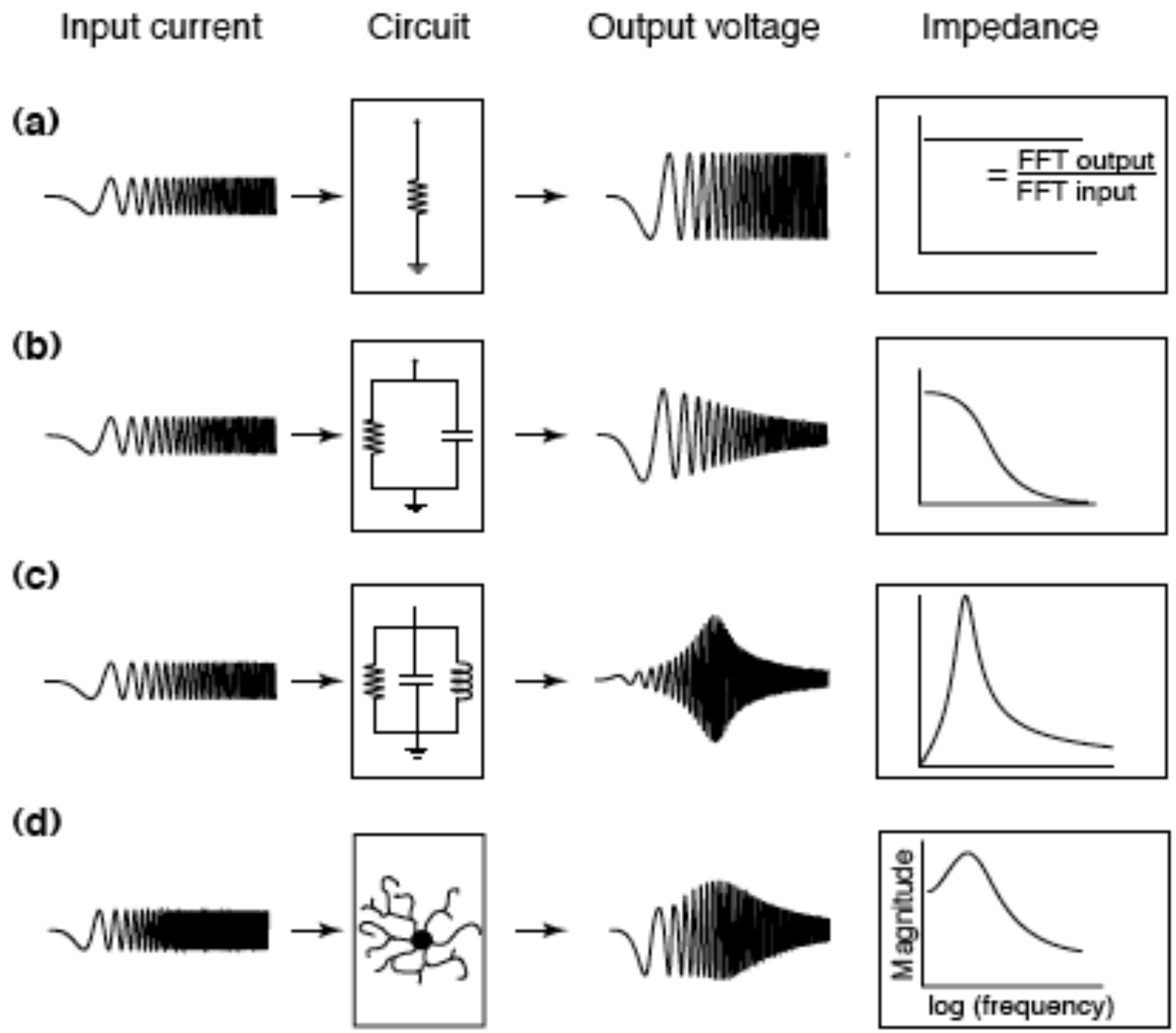
¿Que determina el rango de frecuencia caraterística de cada ritmo cerebral?

A grandes razgos, existen dos explicaciones:

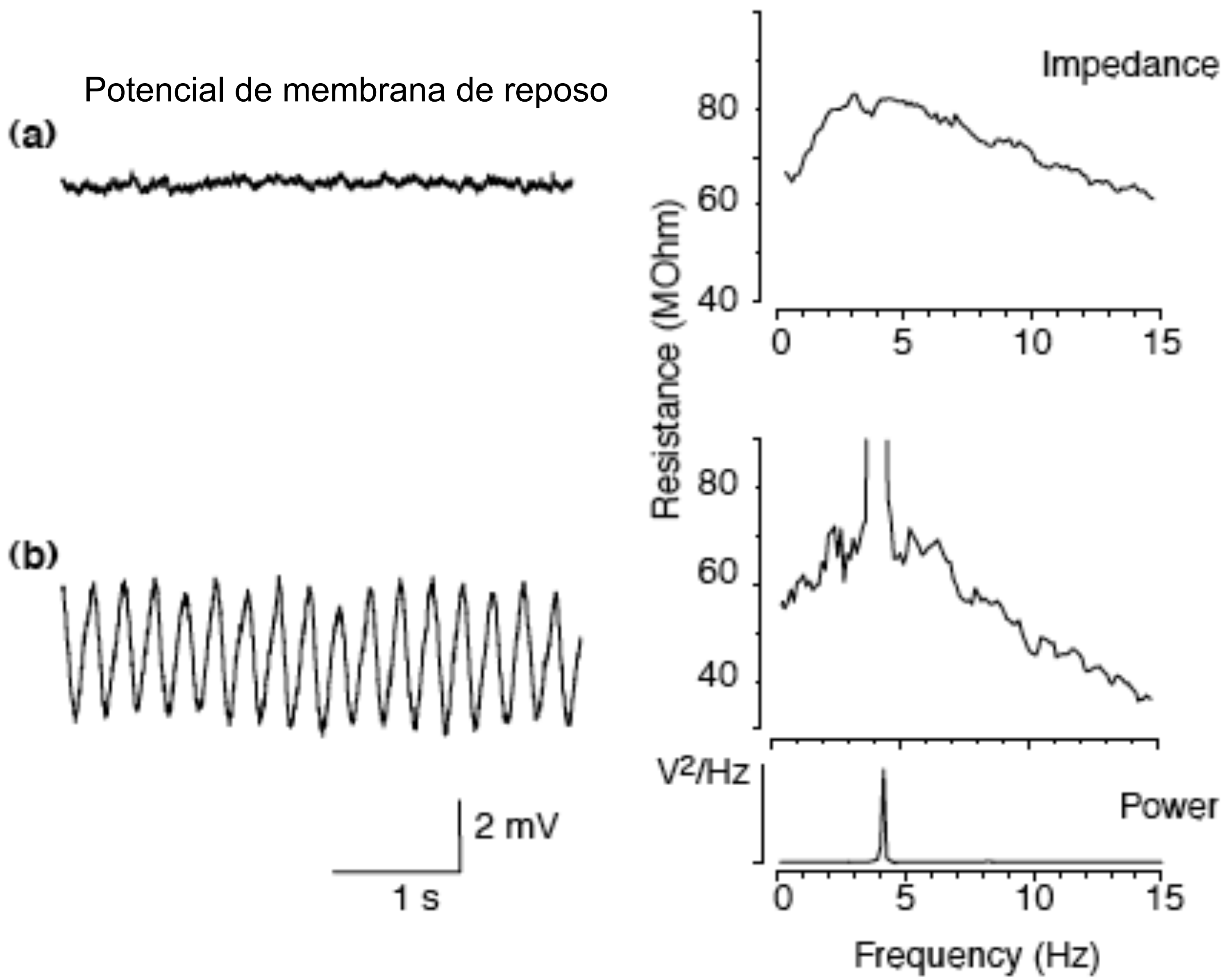
Una invoca a patrones de conectividad entre neuronas, y las propiedades dinámicas de las sinapsis que intervienen, de tal forma que circuitos de neuronas principales (excitatorias), conectadas con interneuronas inhibitorias generen patrones rítmicos de retroalimentación (activación-inhibición) que producen actividad oscilatoria en neuronas fundamentalmente no oscilantes (Traub R.D. et al. 1991).

Otra explicación, sugiere que la ritmicidad de redes de neuronas se origina a partir del acoplamiento de subunidades oscilatorias, cada una de las cuales posee preferencia por una frecuencia, determinada intrínsecamente (Llinás R. 1988).

RESONANCIA NEURONAL ES UNA PROPIEDAD DE LA IMPEDANCIA



Preferencia por frecuencias de neuronas de la oliva inferior

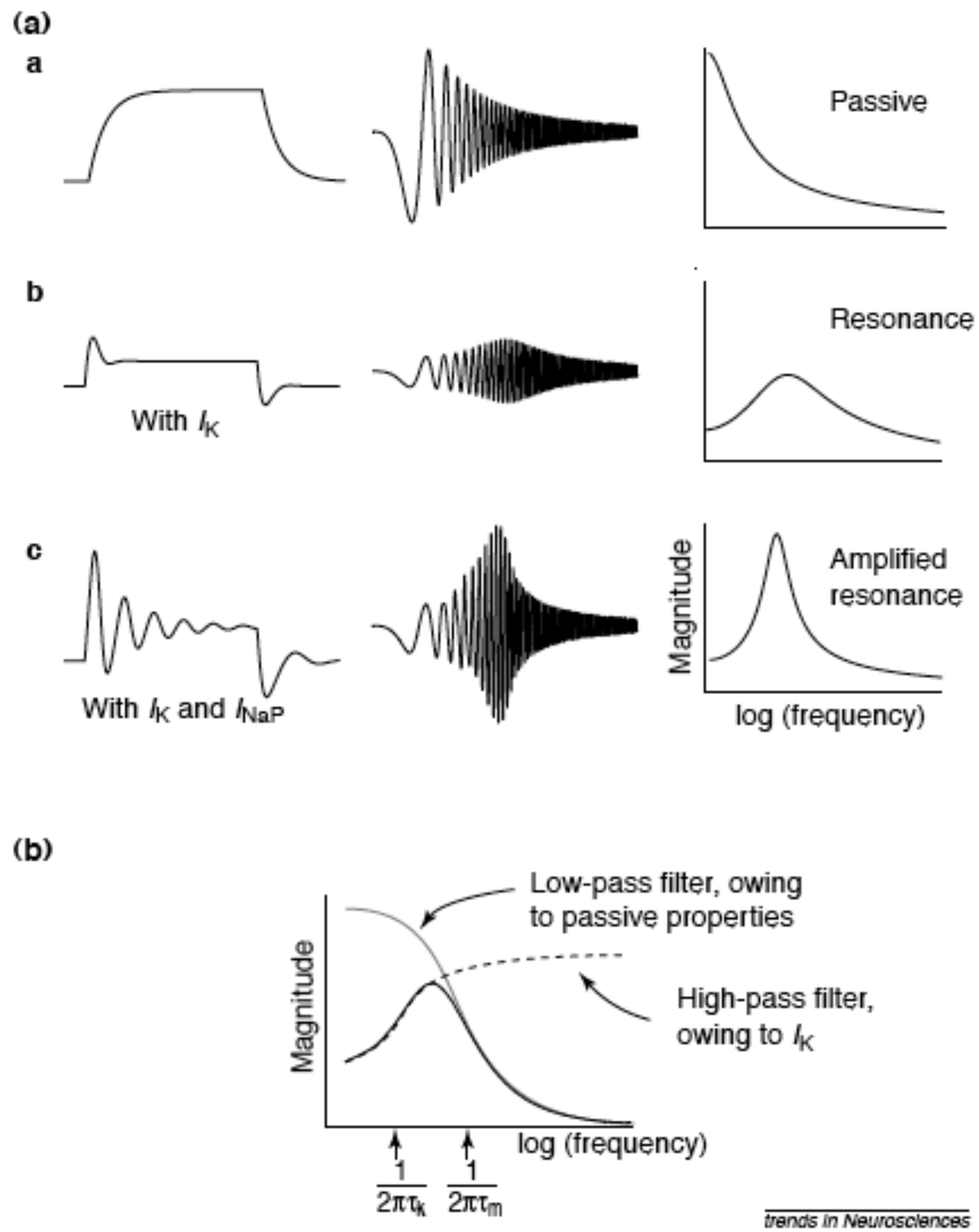


Los canales iónicos estan involucrados en la generación intrínseca de oscilaciones del potencial de membrana

Las oscilaciones subumbral del potencial de membrana observadas en neuronas de la oliva inferior son dependientes de la presencia de corrientes de Calcio activadas por Bajo-Voltaje (I_T currents).

Tanto las oscilaciones como la resonancia neuronal son eliminadas por bloqueo farmacológico de I_T

Combinación de propiedades activas (pasa-alto) y pasivas (pasa-bajo) para generar resonancia en neuronas



Interneuronas a distancia permiten la generación de oscilaciones robustas

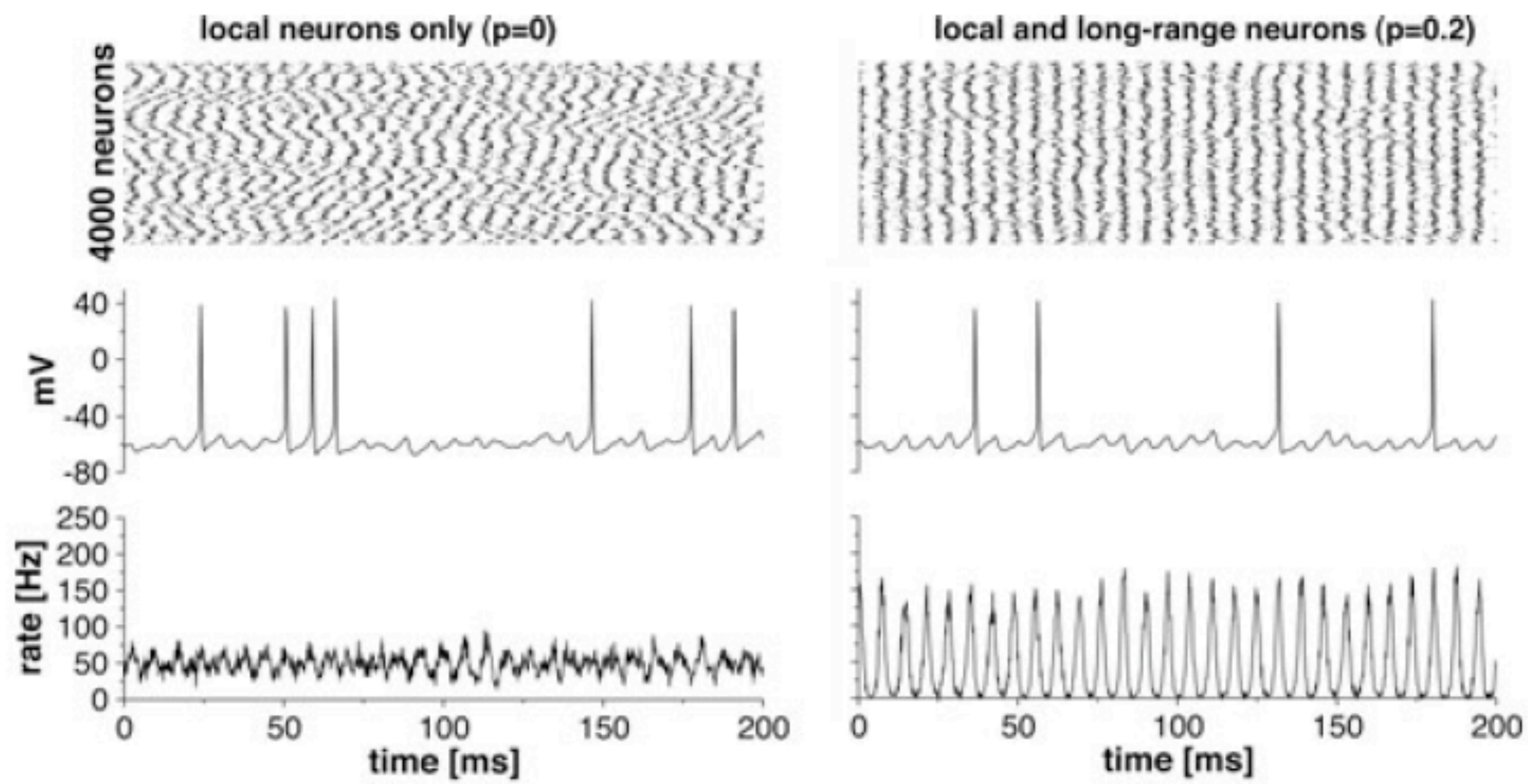


Figure 3.9. In networks with only local inhibitory connections, no oscillations emerge (left: top, spike raster of individual neurons; middle, voltage trace of a single representative cell; bottom, population synchrony). Adding a small subset of long-range interneurons to the locally connected population, with 20 percent of the contacts distributed according to a power-law distribution, robust oscillation emerges (right). Reprinted, with permission, from Buzsáki et al. (2004).

Algunas configuraciones …

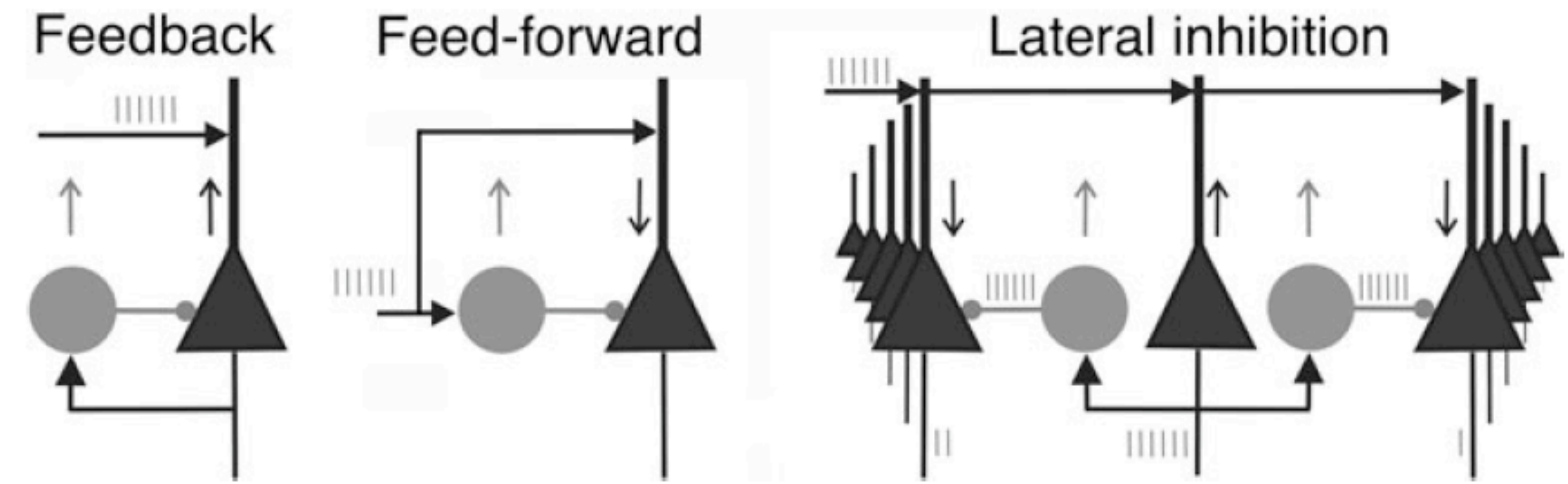


Figure 3.2. Negative (inhibitory) feedback provides stability. Feedforward inhibition dampens ("filters") the effect of afferent excitation. Lateral inhibition provides autonomy (segregation) of neurons by suppressing the similarly activated neighboring neurons ("winner take all").

Circuiteria básica

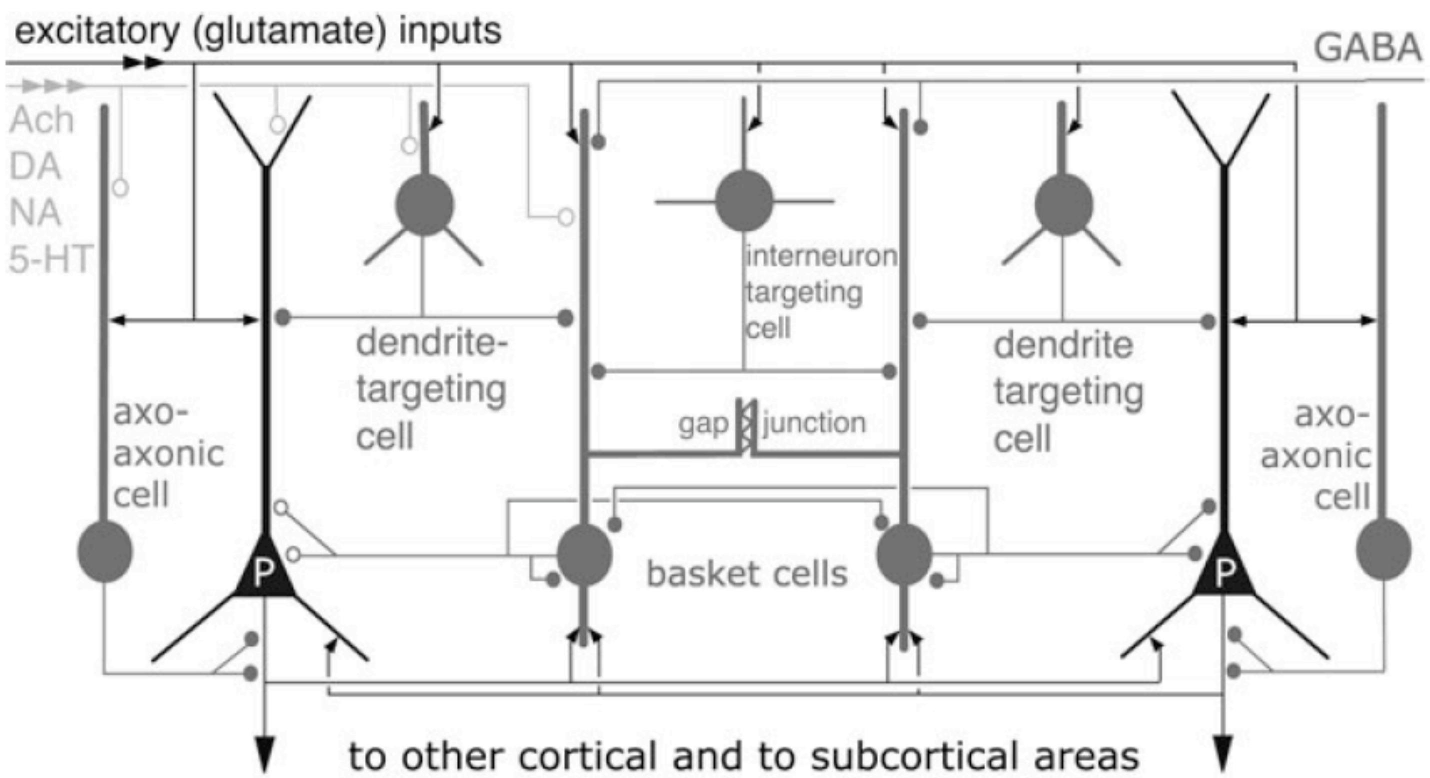
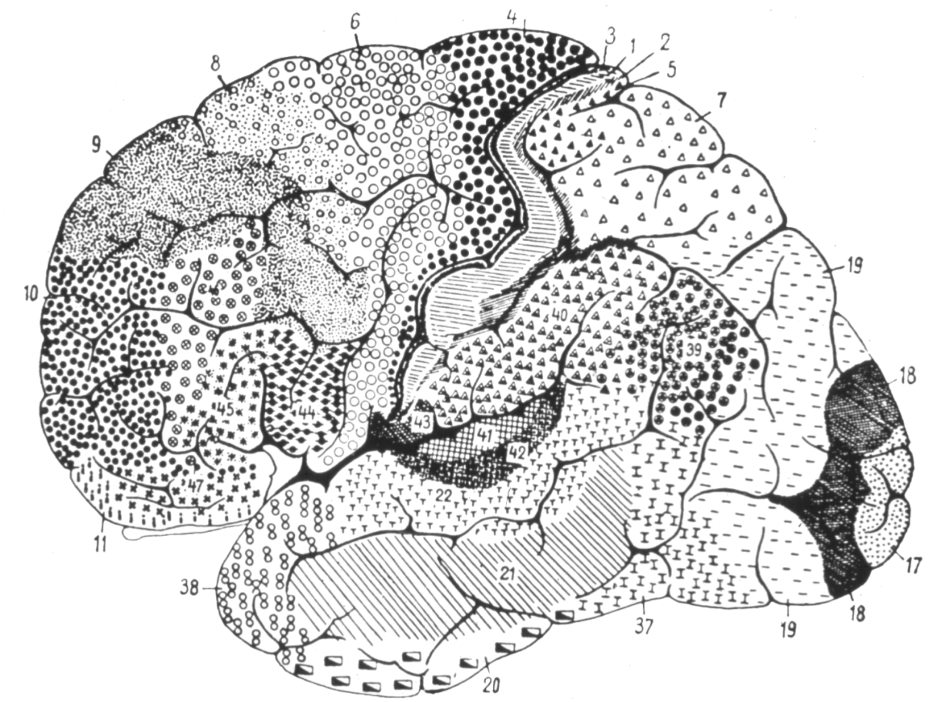


Figure 3.6. The basic cortical circuit, including one type of pyramidal cell (P) and representative interneuron classes. Perisomatic control of pyramidal cell is secured by basket and axoaxonic (chandelier) neurons. Both pyramidal cells and interneurons are innervated by extracircuit excitatory and inhibitory inputs as well as by subcortical neurotransmitters: acetylcholine (ACh), dopamine (DA), norepinephrine (NA), and serotonin (5-HT, 5-hydroxytryptamine). Modified, with permission, from Somogyi et al. (1998).



Patrones de conectividad

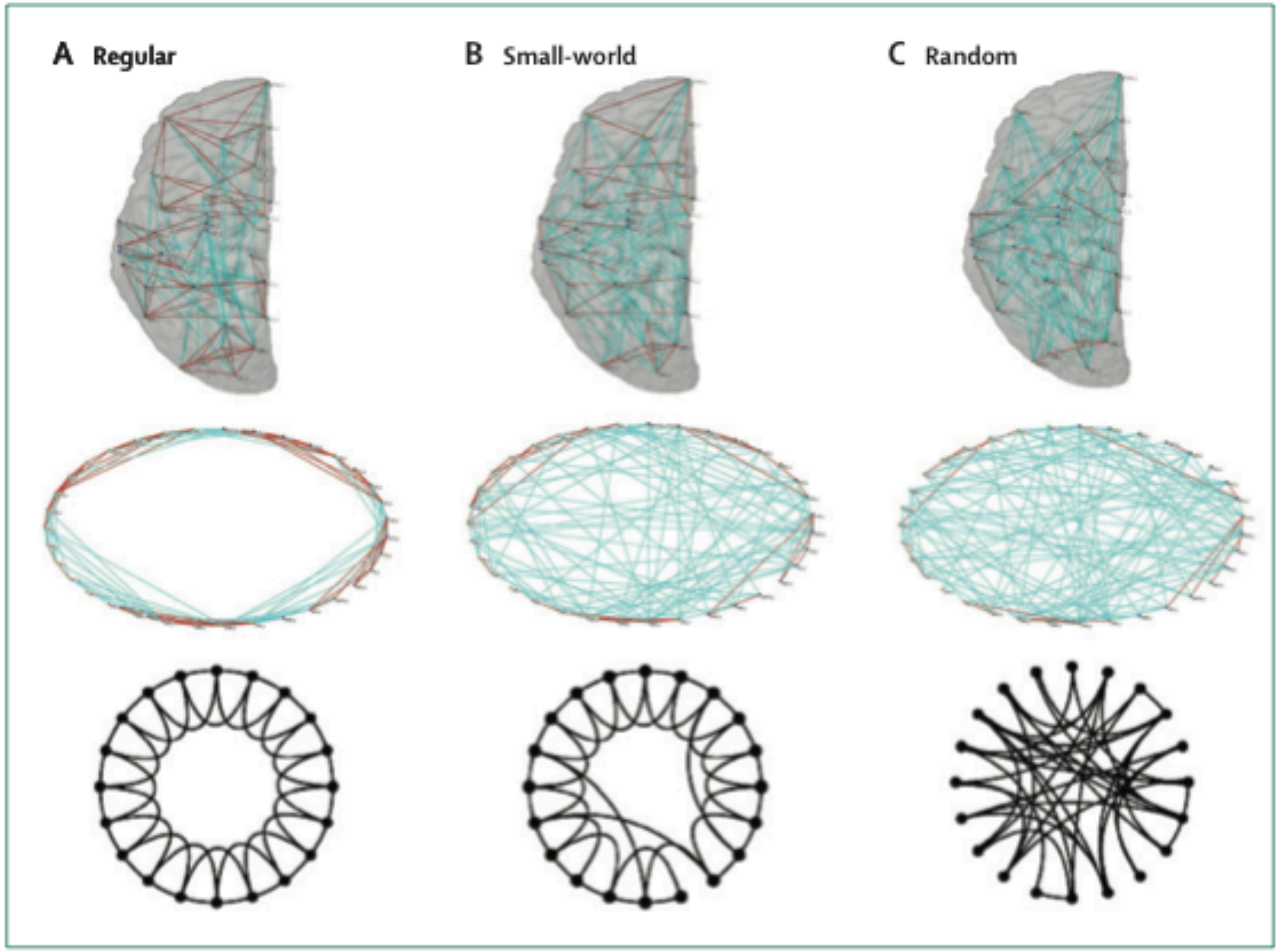
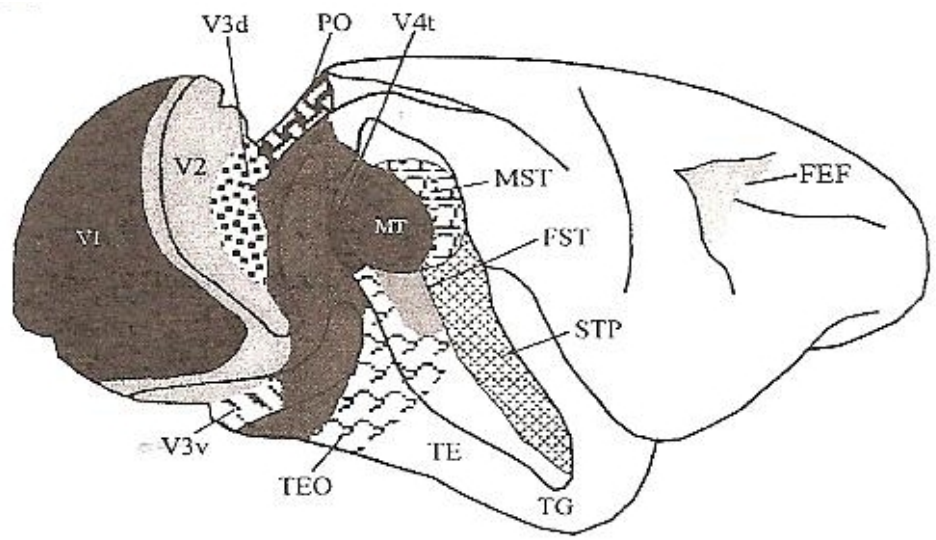
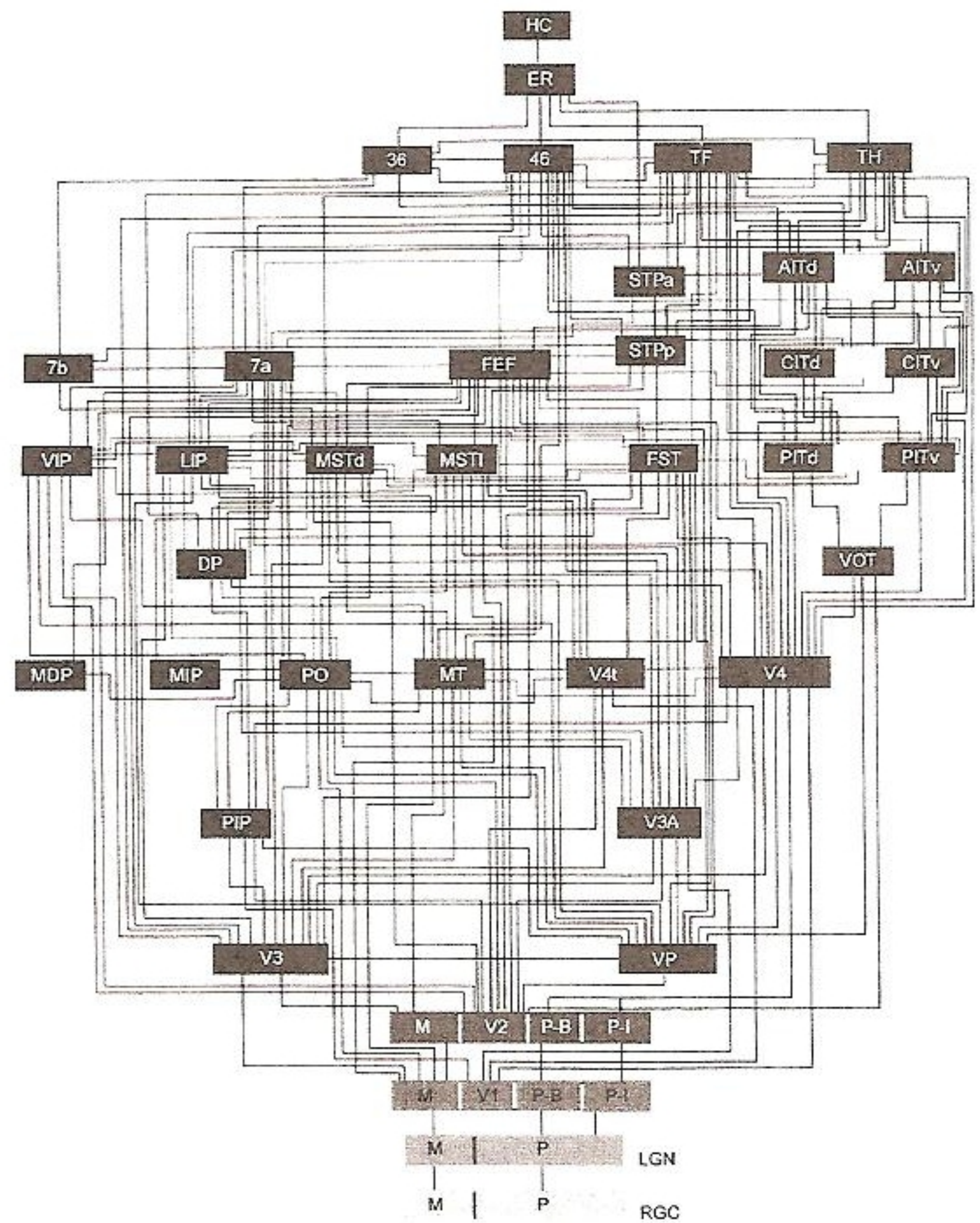


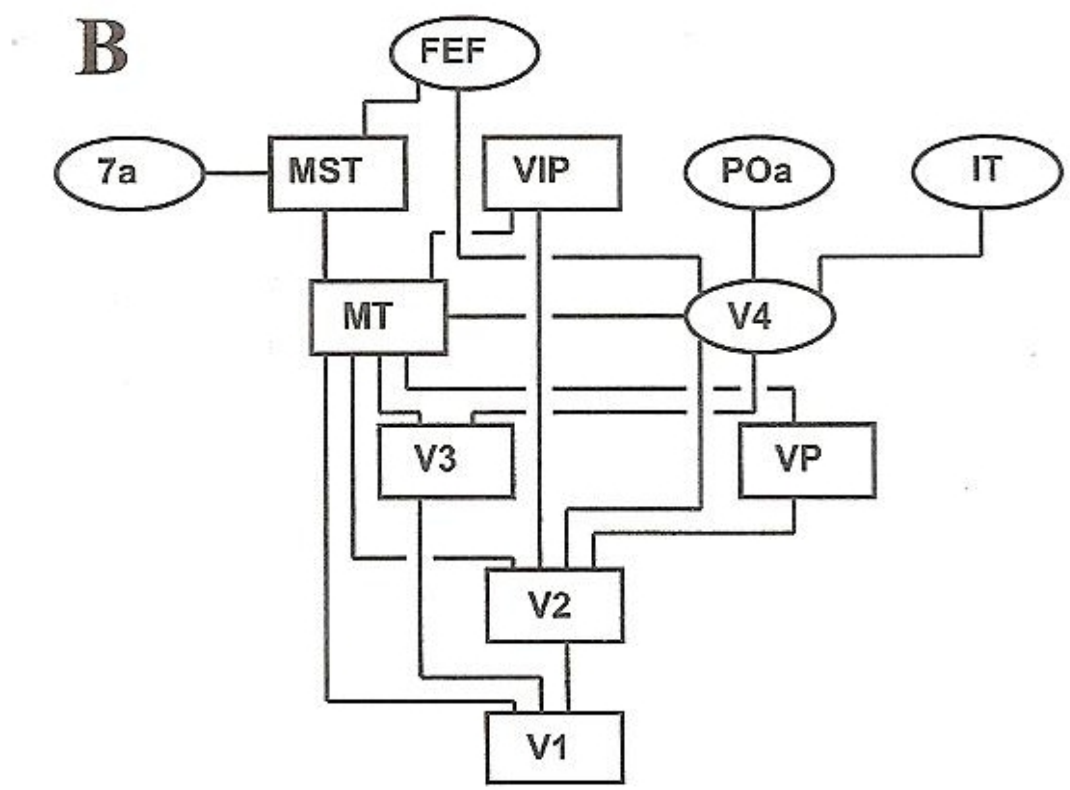
Figure 5: **Schematic representation of a small-world brain functional network and of simulated regular and random networks with 35 nodes and 120 connections**

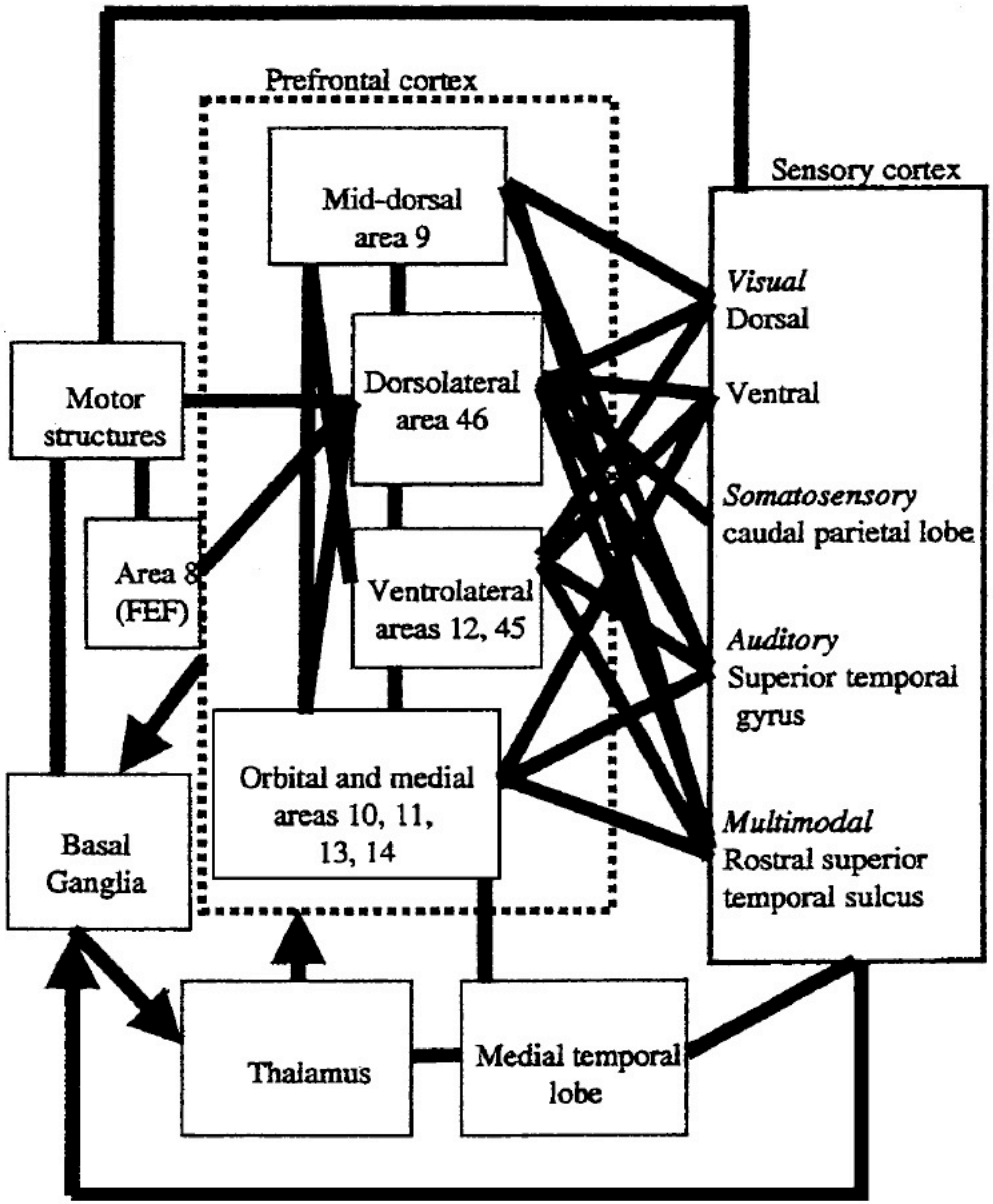
Regular networks (A) have many connections between neighbouring regions (red lines) and few connections with distant nodes (light blue lines). Small-world networks (B) have fewer local connections and more long-distance connections. Random networks (C) have few local connections and many connections between distant regions. Each network is shown overlaid onto a standard template (top row) and in schematic representation (middle row). Nodes represent 35 cortical points of the left hemisphere drawn from the automated anatomical labelling template, and edges represent functionally connected nodes. The real-world network was extracted from a single person, the corresponding regular (A) and random (C) networks were simulated with the Brain Connectivity Toolbox.[89] The corresponding theoretical Watts–Strogatz network models are also shown (bottom row). Adapted from Watts and Strogatz[38] by permission of Macmillan Publishers Ltd.

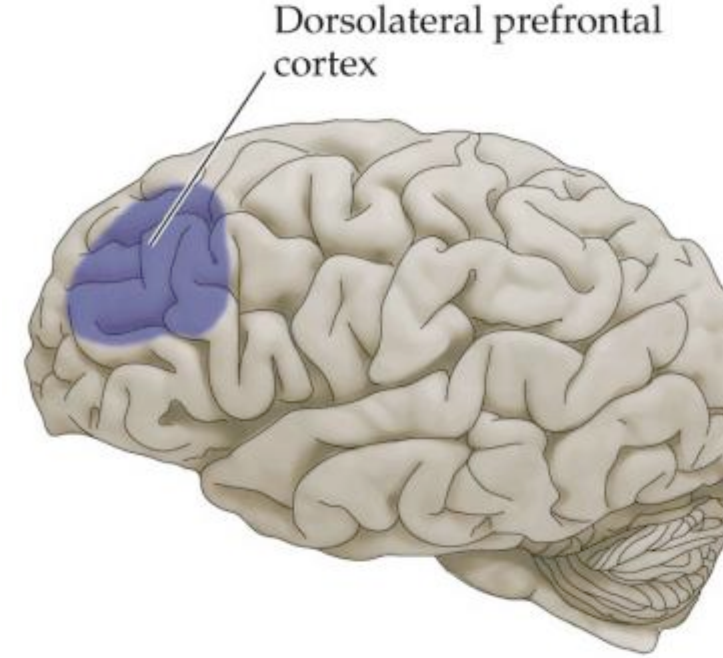
Conectividad de la corteza visual








Prefrontal cortex
Mid-dorsal area 9
Dorsolateral area 46
Ventrolateral areas 12, 45
Orbital and medial areas 10, 11, 13, 14
Motor structures
Area 8 (FEF)
Basal Ganglia
Thalamus
Medial temporal lobe
Sensory cortex
Visual
Dorsal
Ventral
Somatosensory
caudal parietal lobe
Auditory
Superior temporal gyrus
Multimodal
Rostral superior temporal sulcus


Dorsolateral prefrontal cortex

Conectividad funcional

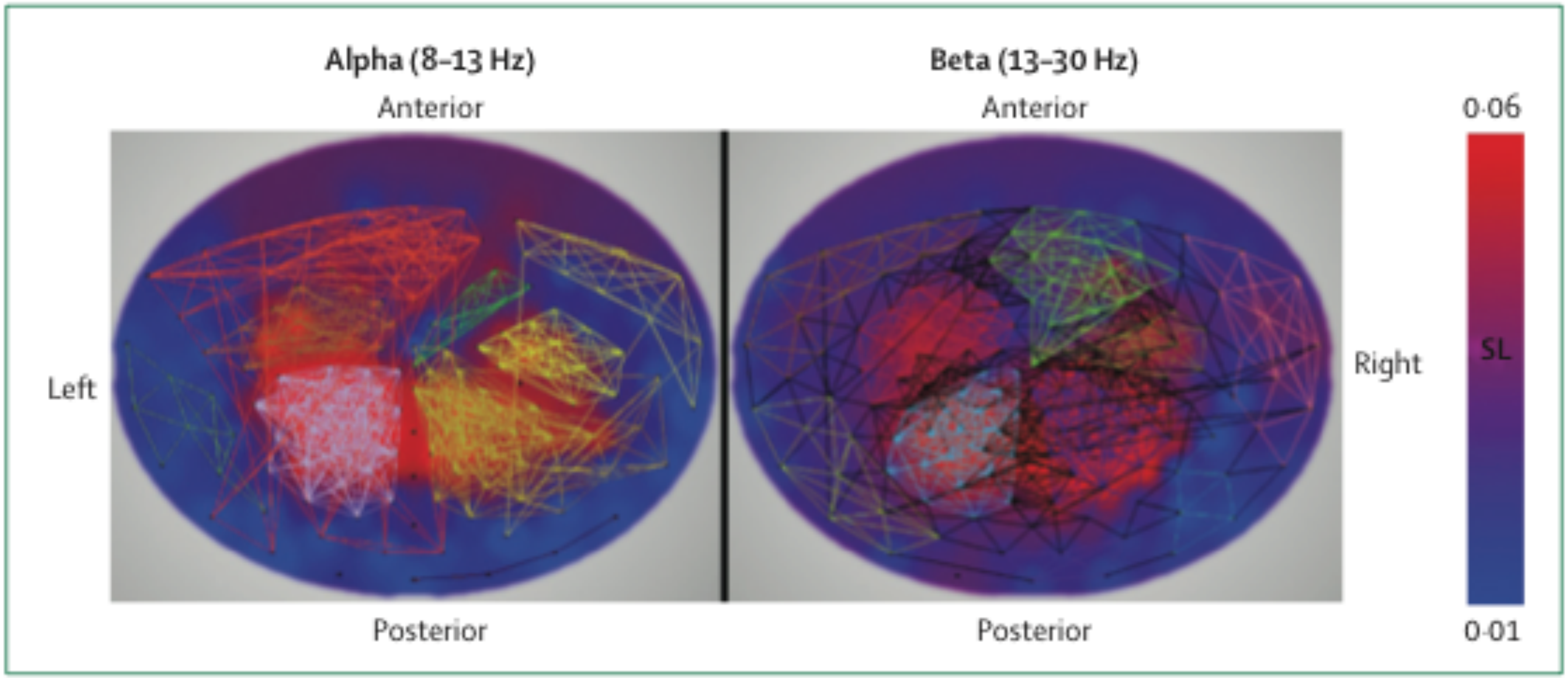
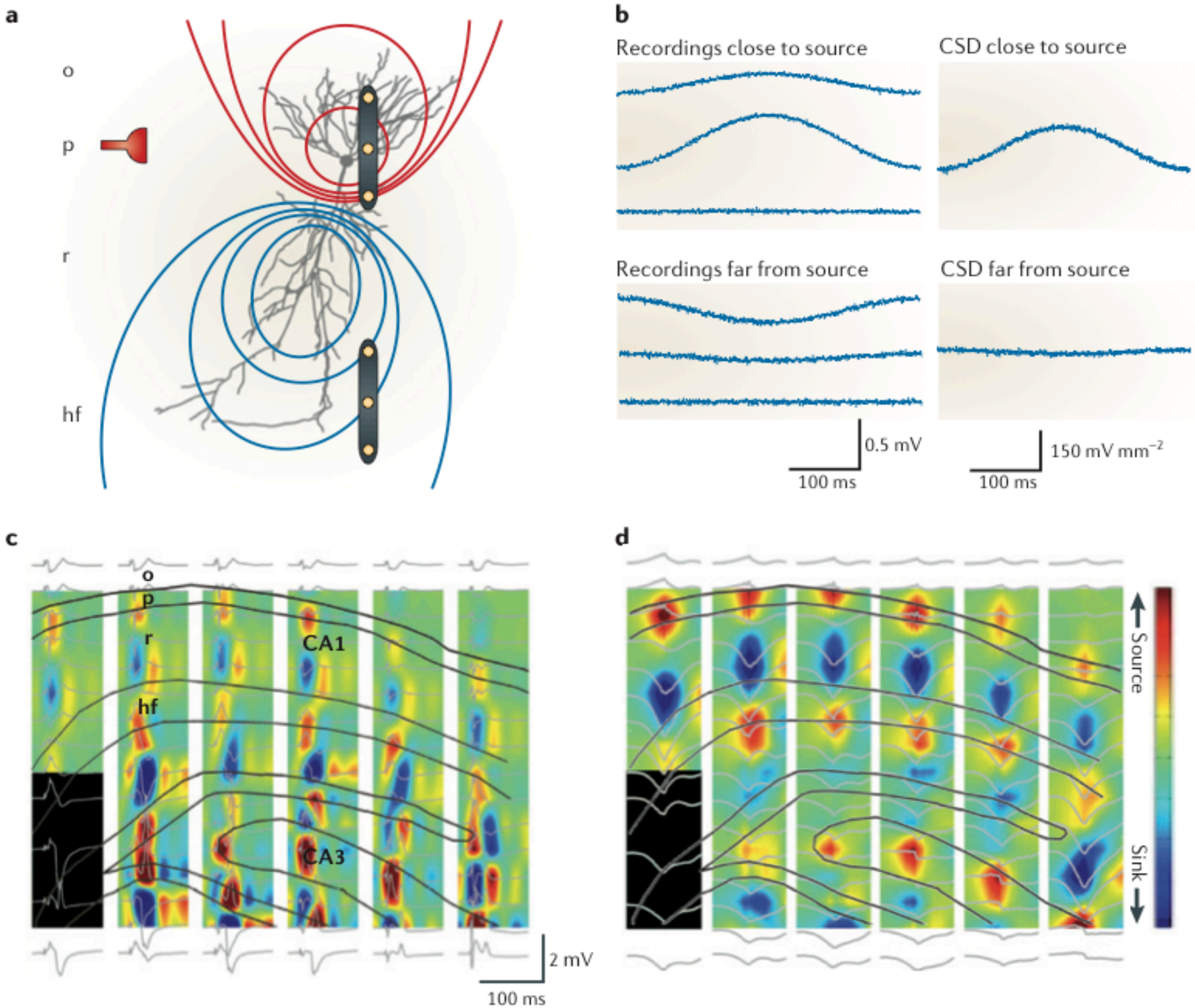


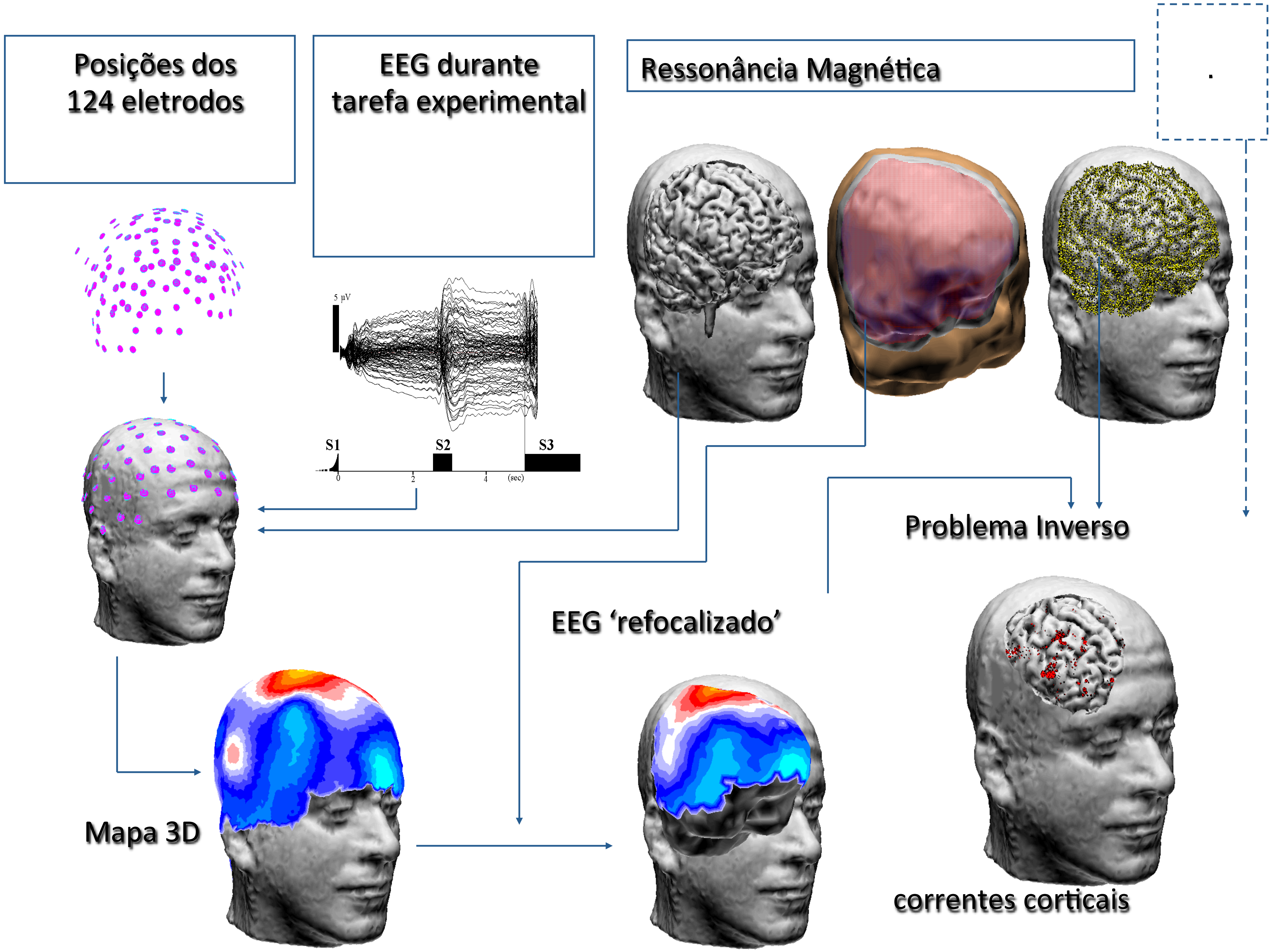
***Figure 3*: Functional connectivity on resting-state MEG in healthy people**

Headplot showing functional MEG network of a healthy woman aged 63 years in the alpha (8–13 Hz) and beta (13–30 Hz) frequency ranges.[13] Coloured lines show different functional subnetworks (modules), black lines represent their interconnections (only shown in beta-band example). Background colours show connectivity strength (red are hub—ie, highly connected—regions). MEG=magnetoencephalography. SL=synchronisation likelihood.[13]

Current source density



Análisis de fuente



Reconstrucción de generadores de corrientes corticales