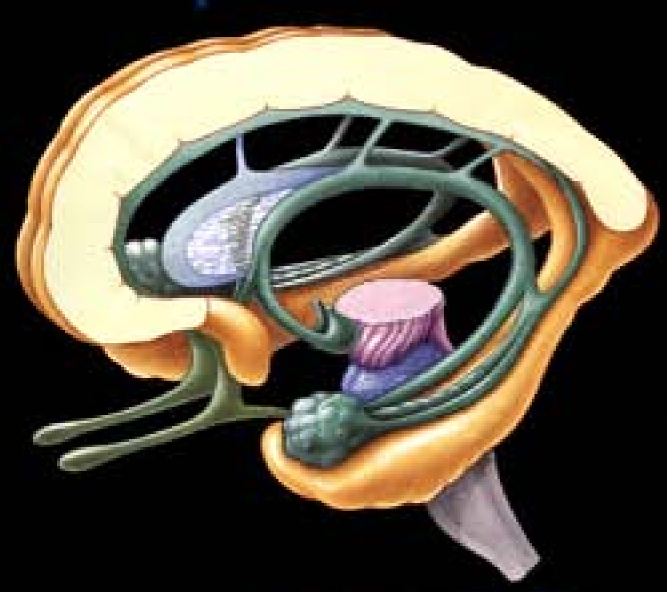
Hippocampal development & Synaptogenesis



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Module « Cellular Neurobiology & Development »
Magistère Européen de Génétique
UFR Sciences du Vivant - Université Denis Diderot Paris VII
22 septembre 2008

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Hippocampal development & Synaptogenesis

1. **Introduction to neuroanatomy**
   - Neurulation
   - Differenciation : Forebrain-Midbrain-Hindbrain
   - Major structures of the brain
2. **Hippocampus & the limbic system**
   - Localization in human and rodents
   - General function
   - Connections and cellular populations
3. **Formation of the hippocampus and dentate gyrus**
   - Migration of excitatory neurons
     - pyramidal cells & granule cells
   - Migration of inhibitory interneurons
4. **Dissociated hippocampal neurons in culture**
   - The sandwich model of Gary Banker
   - Acquisition of neuronal polarity
   - Synaptogenesis

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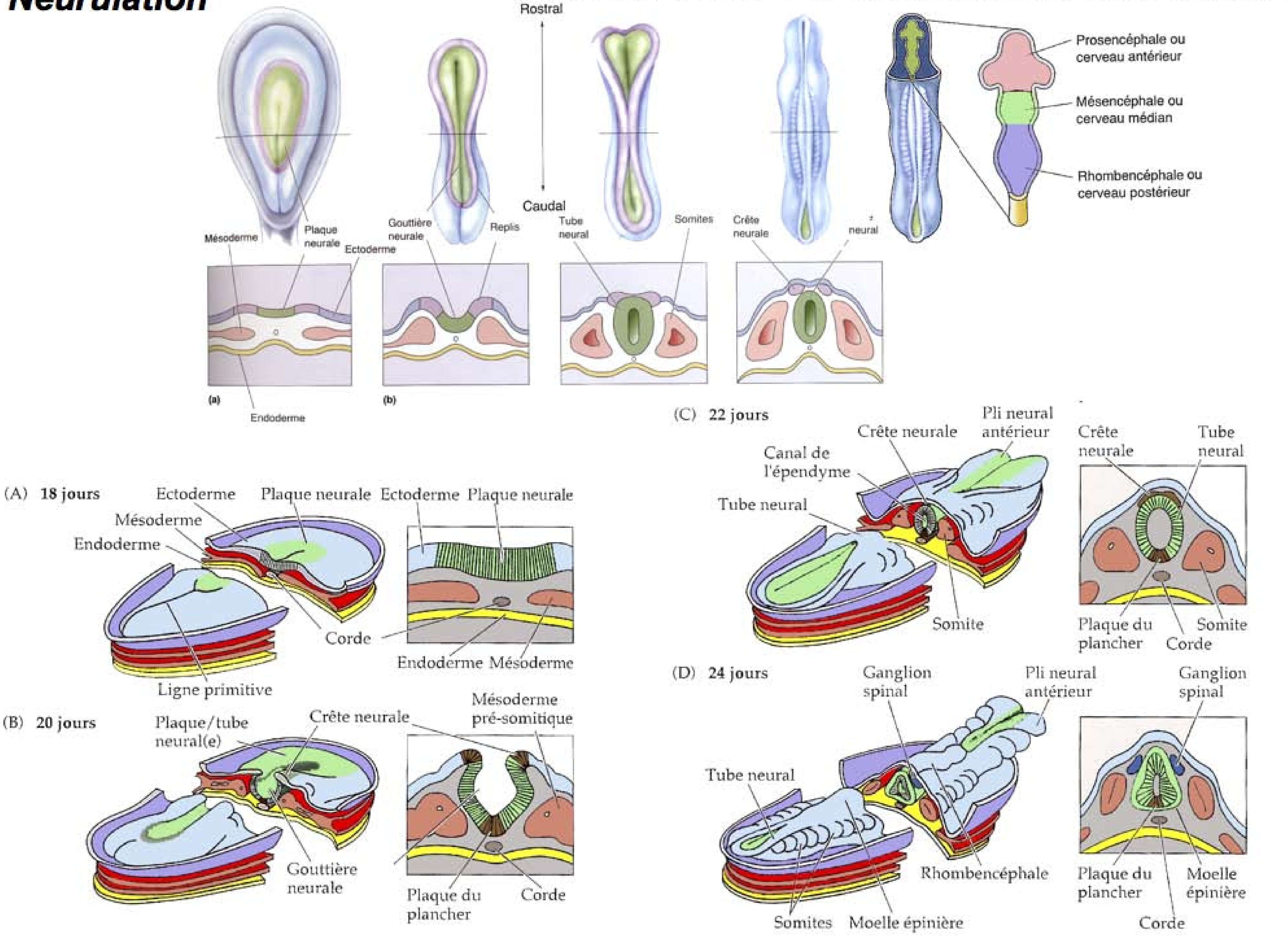
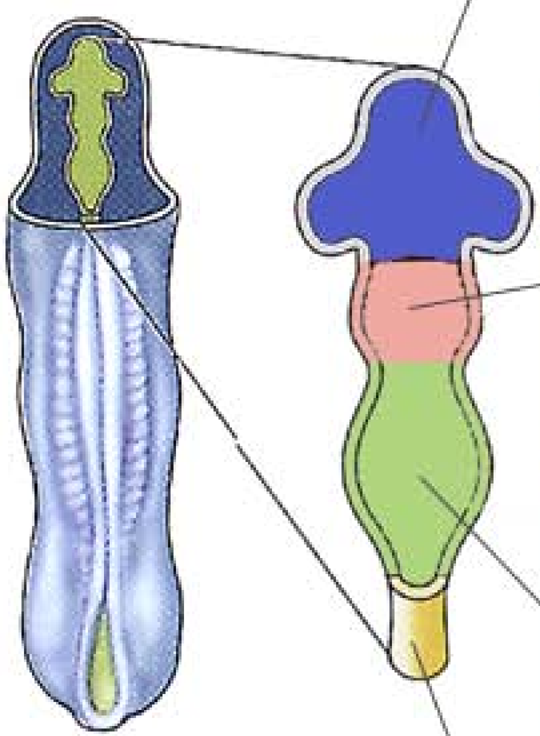
Neurulation



Differenciation



PROSENCEPHALON
Prosencéphale
FOREBRAIN *Cerveau antérieur*

Lateral ventricules

- Optic vesicles: Rétina, Optic nerve
- Telencephalon: Olfactory bulb, Cerebral cortex, Cortical White matter, Corps callosum, Internal capsule
- Diencephalon: Thalamus, Hypothalamus

MESENCEPHALON
Mésencéphale
MIDBRAIN *Cerveau moyen*
Third ventricule

- Tectum, Tegmentum

RHOMBENCEPHALON
Rhombencéphale
HINDBRAIN - *Cerveau postérieur*

Fourth ventricule

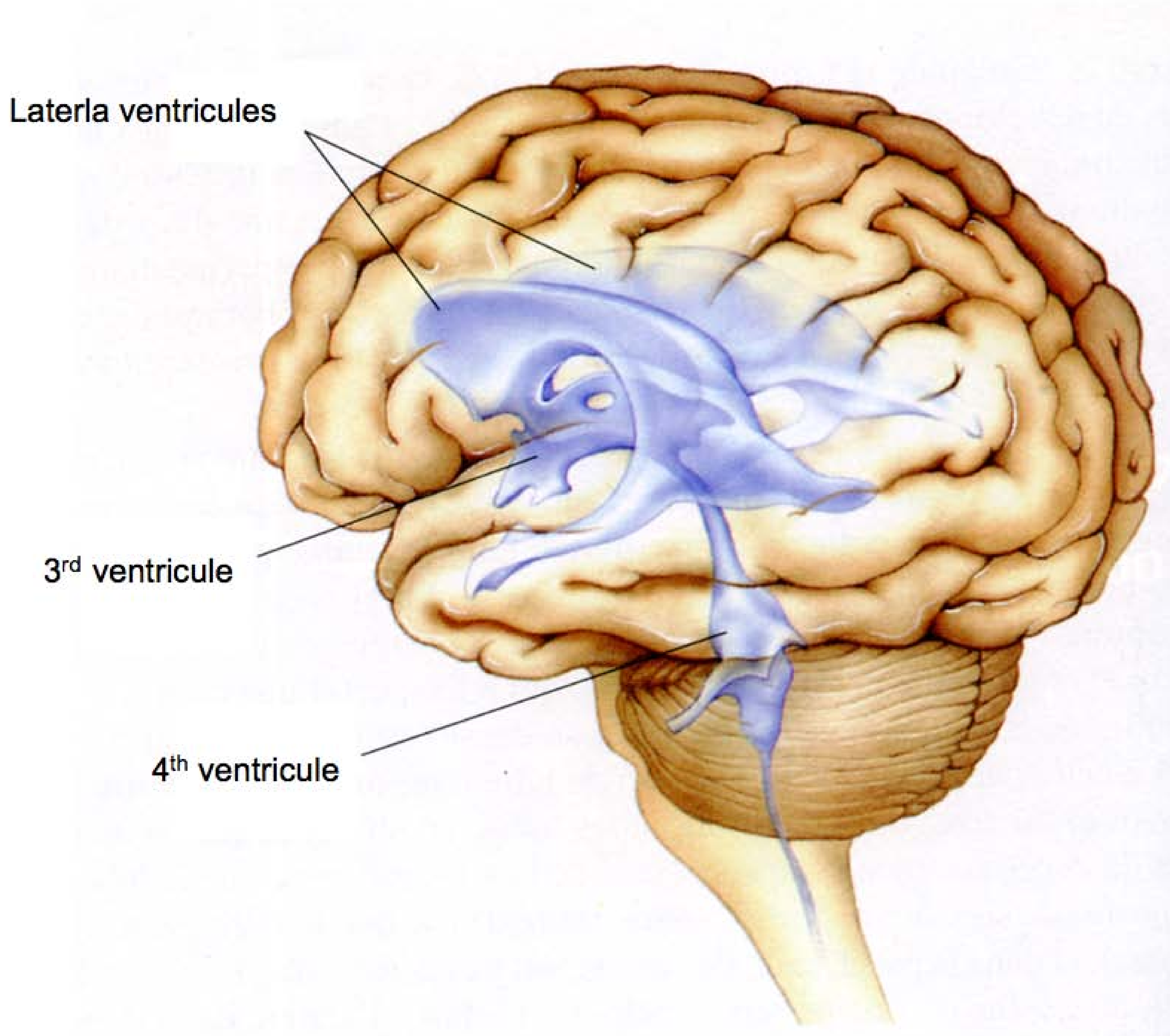
- Metencephalon: Cerebellum, Pons
- Myelencephalon: Bulb

SPINAL CORD
Moëlle épinière

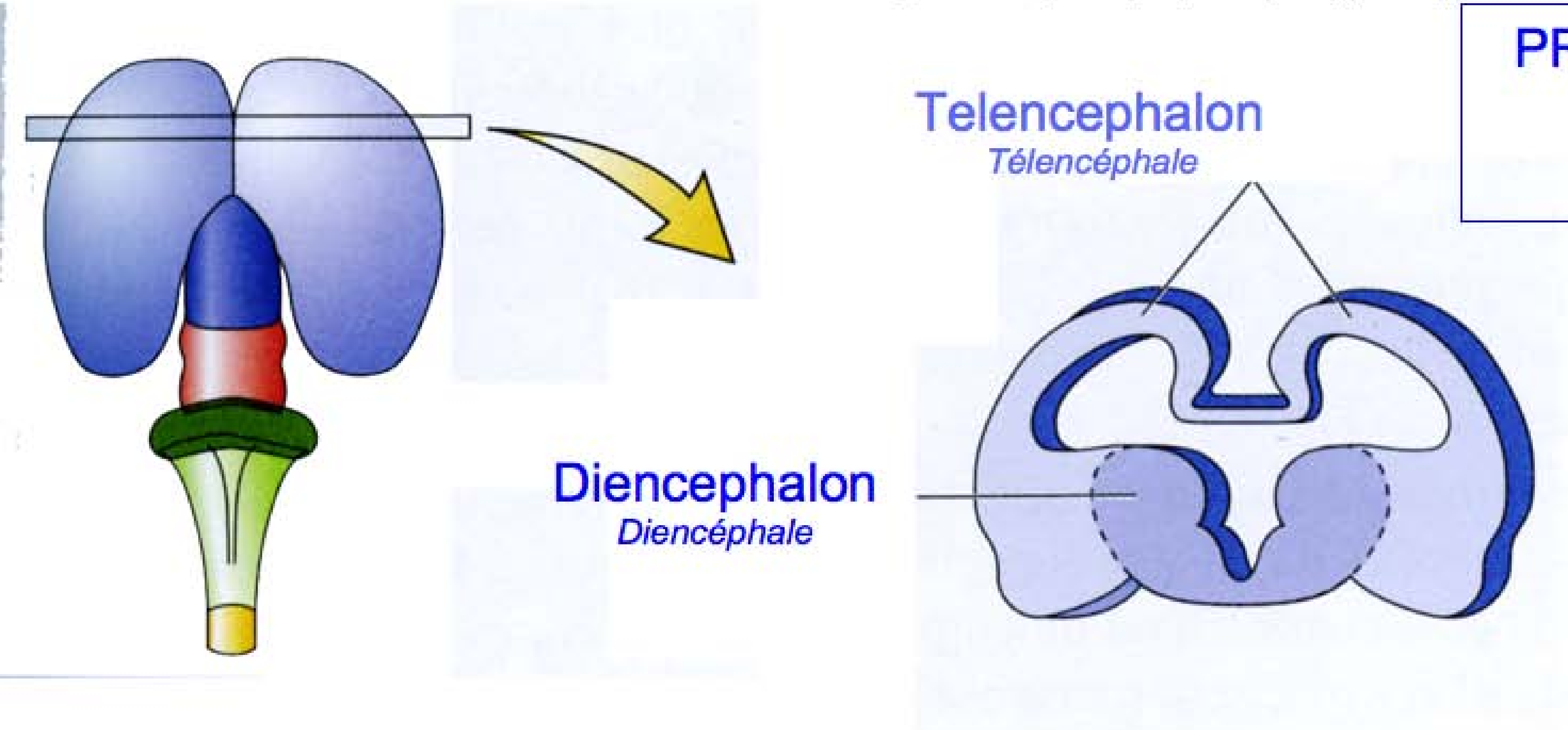
Central canal

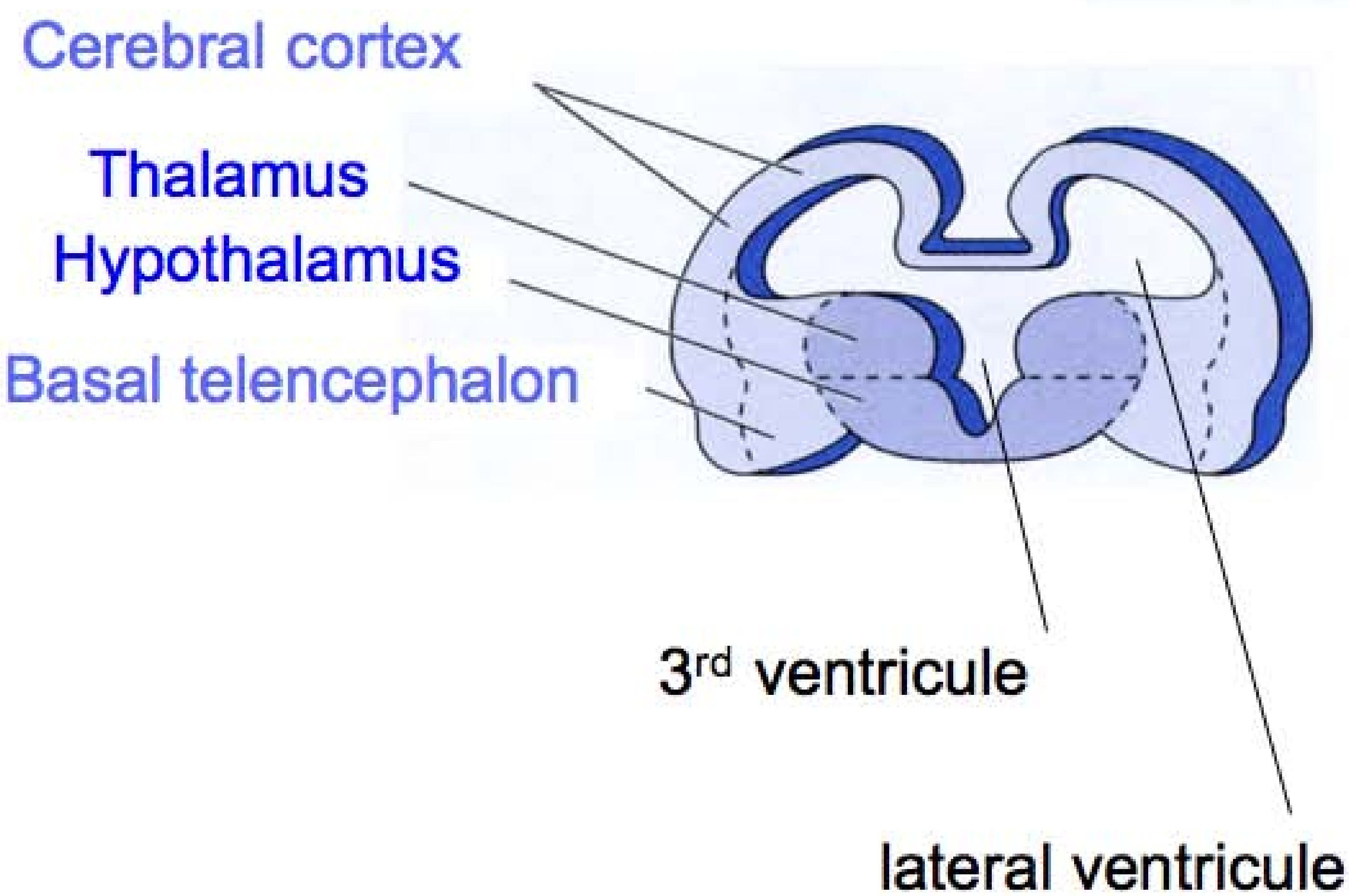
- Spinal cord

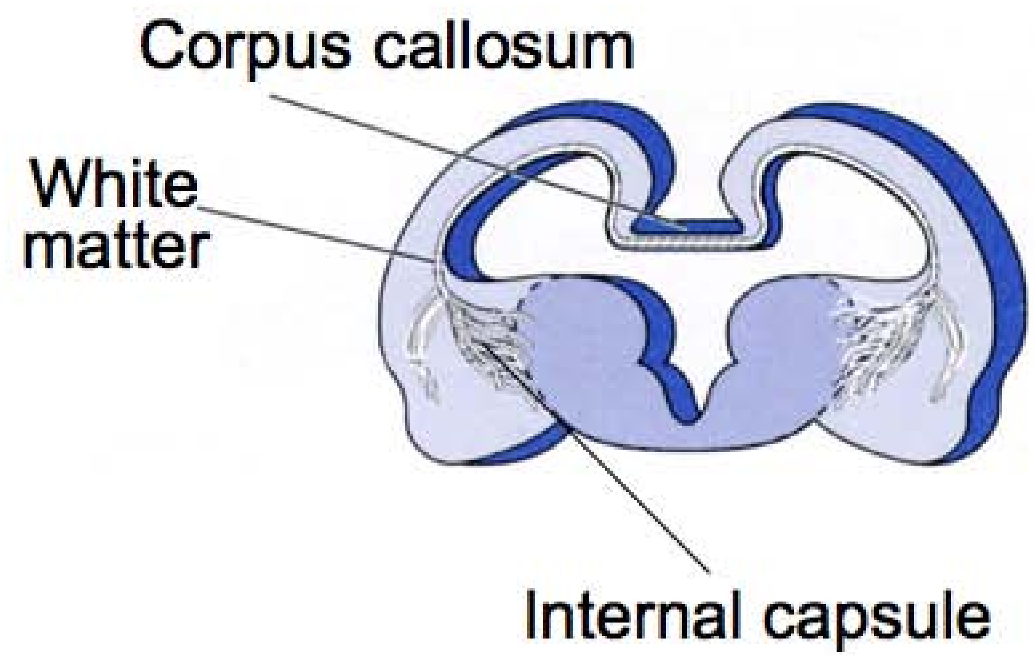
The rostral part of the neural tube differenciates to form the three primitive vesicles at the origin of the brain.

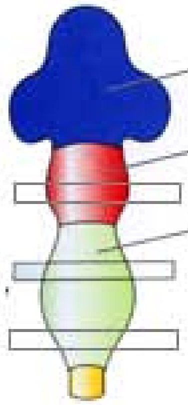

Laterla ventricules
3rd ventricule
4th ventricule

PROSENCEPHALON
FOREBRAIN
Prosencéphale







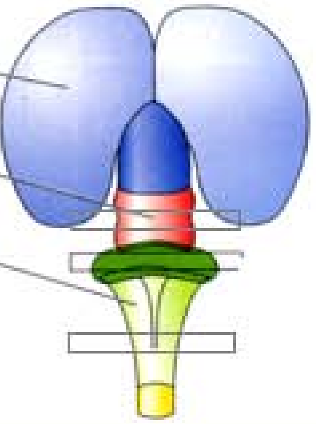


FOREBRAIN - PROSENCEPHALON

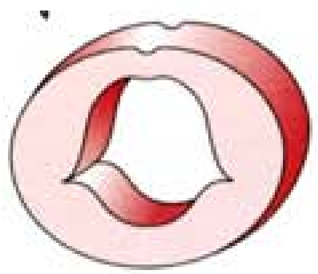
MIDBRAIN - MESENCEPHALON

HINDBRAIN - RHOMBENCEPHALON

Differenciation



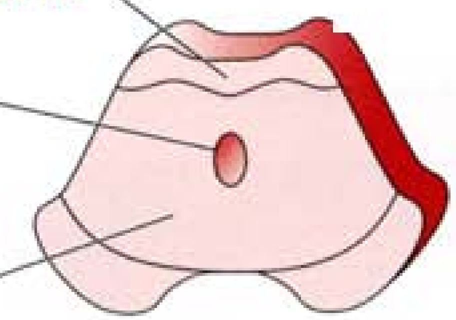
MESENCEPHALON
Mésencéphale



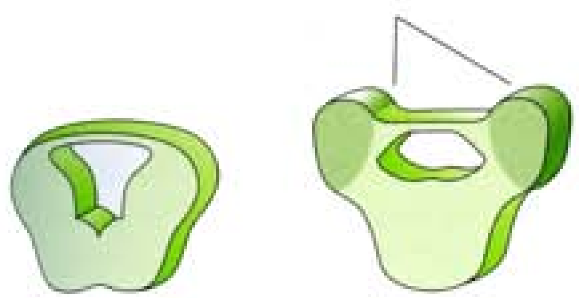
Tectum

Cerebral aqueduct

Tegmentum



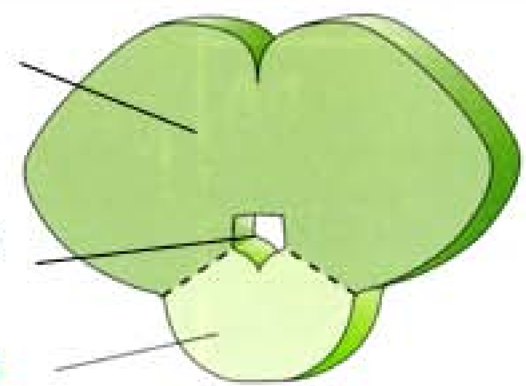
Rhombencephalic lips



Cerebellum

4th ventricule

Pons

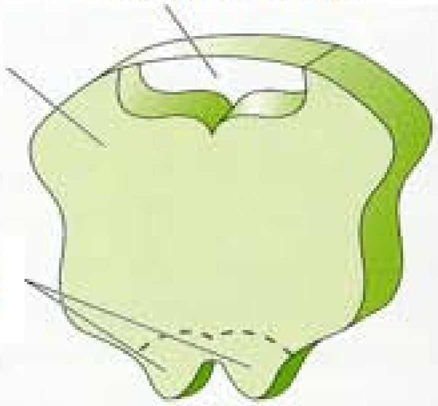


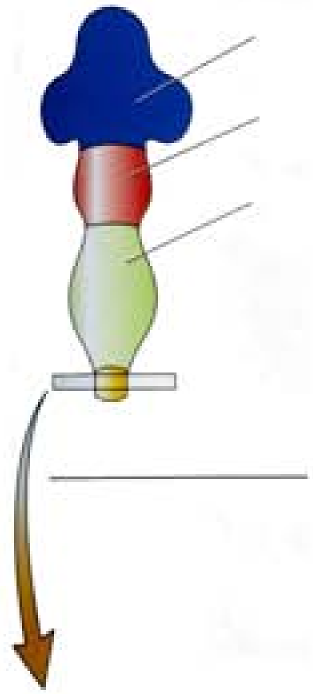
RHOMENCEPHALON
Rhombencéphale

4th ventricule

Bulb

Bulb Pyramide



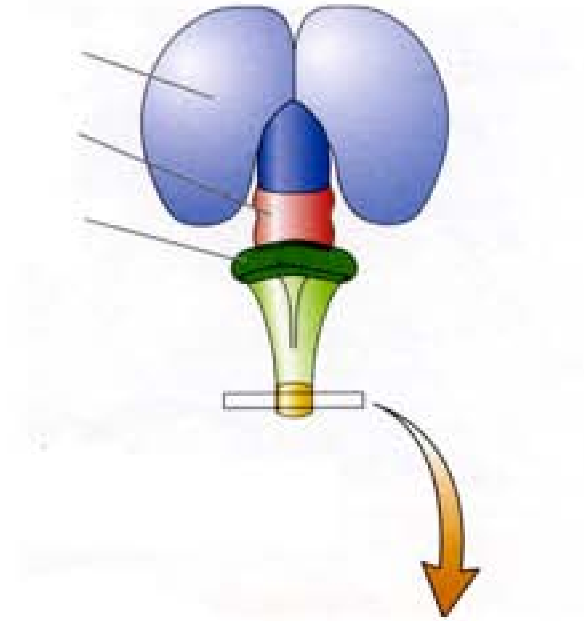


FOREBRAIN - PROSENCEPHALON

MIDBRAIN - MESENCEPHALON

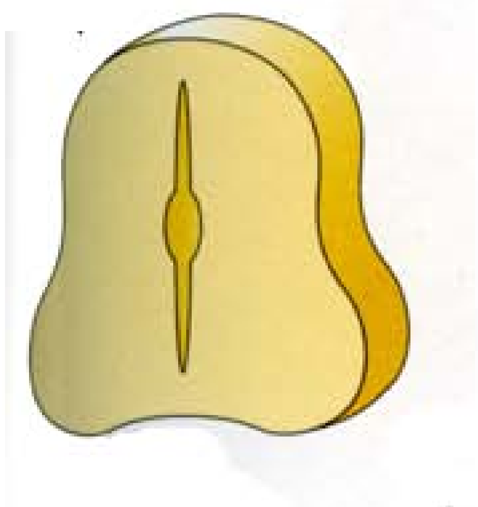
HINDBRAIN - RHOMBENCEPHALON

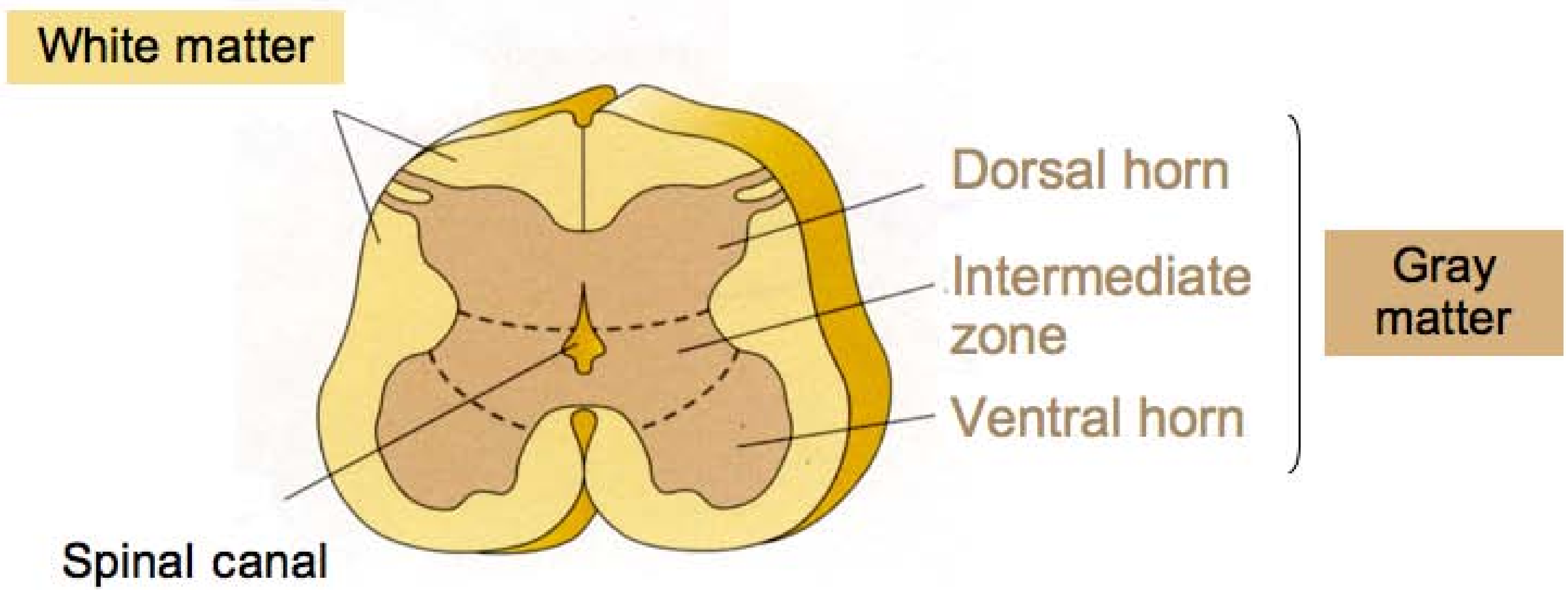
Differenciation

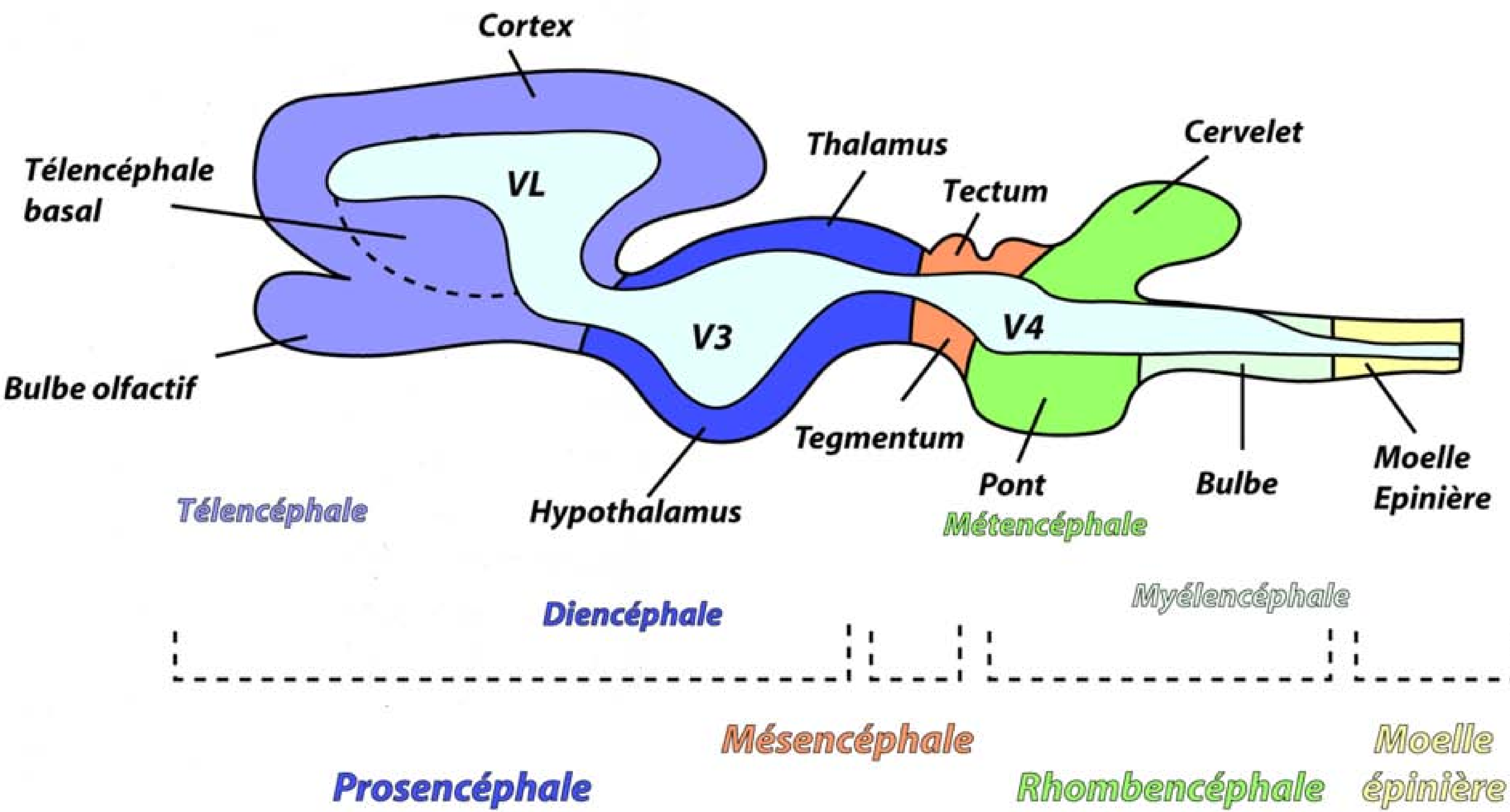


SPINAL CORD

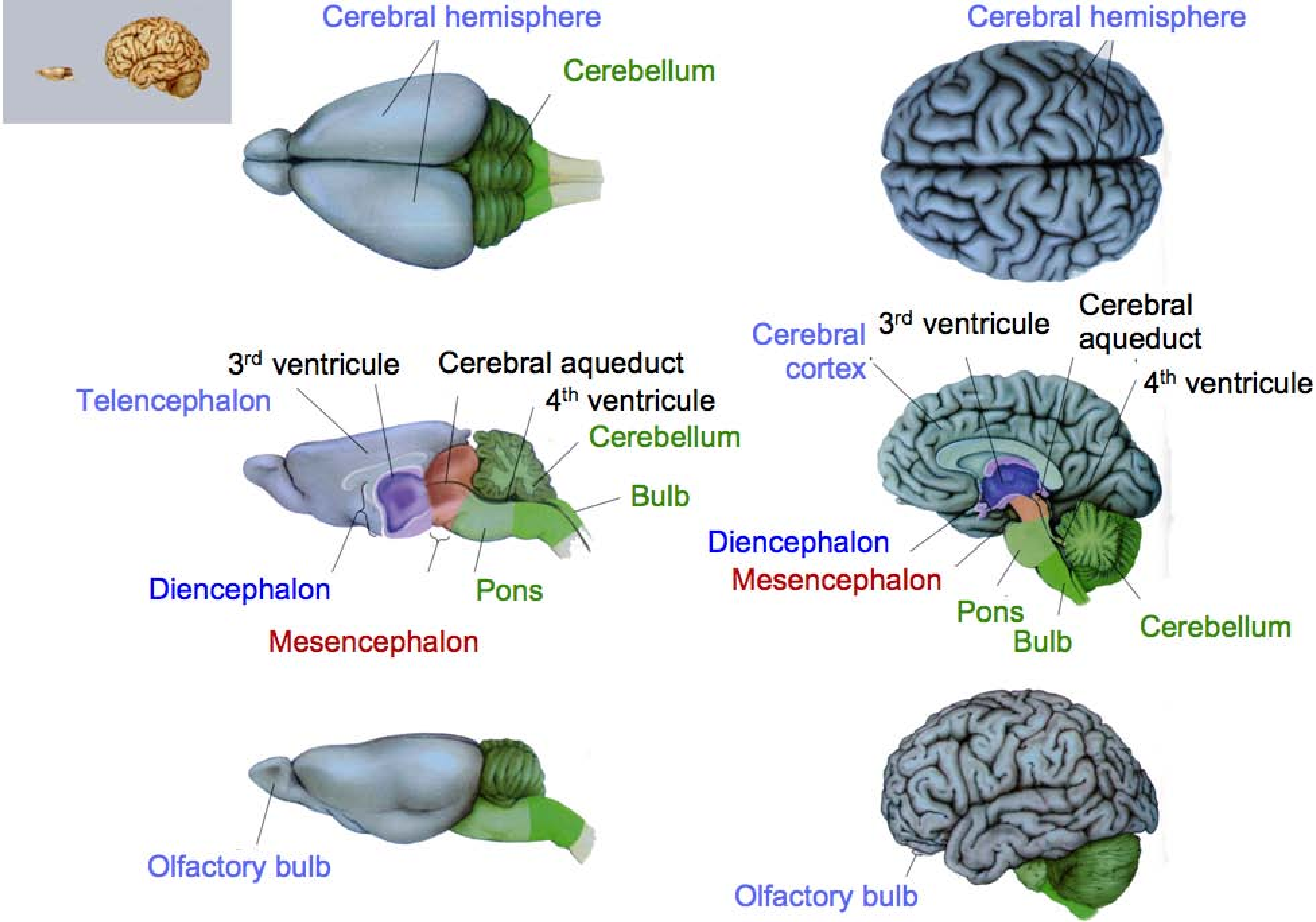
Moëlle épinière







Organisation générale du cerveau des mammifères



PROSENCEPHALON *Prosencéphale*

MESENCEPHALON *Mésencéphale*

RHOMENCEPHALON *Rhombencéphale*

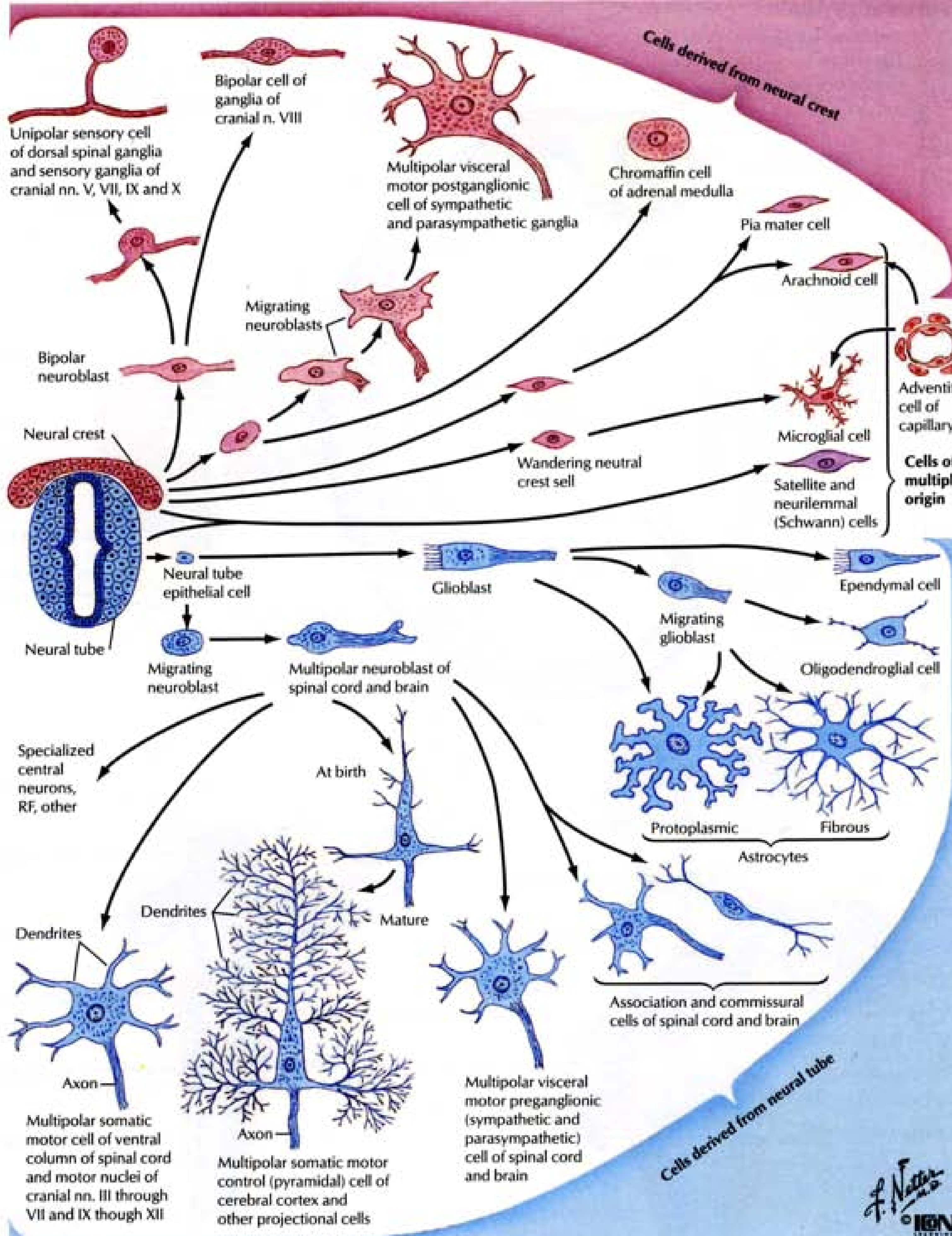
Derived cells from neural tube and neural crest

Neural crest:

- Ganglionar cells (spinal & ANS)
- Chromaffin cells
- Glial cells:
  - Schwann cells
  - Microglia

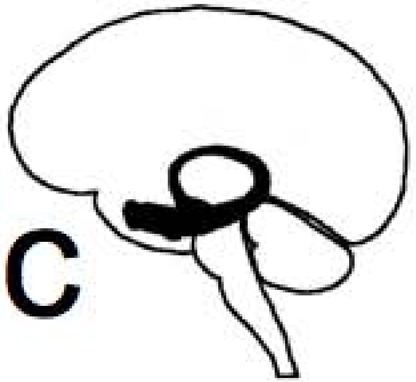
Neural tube:

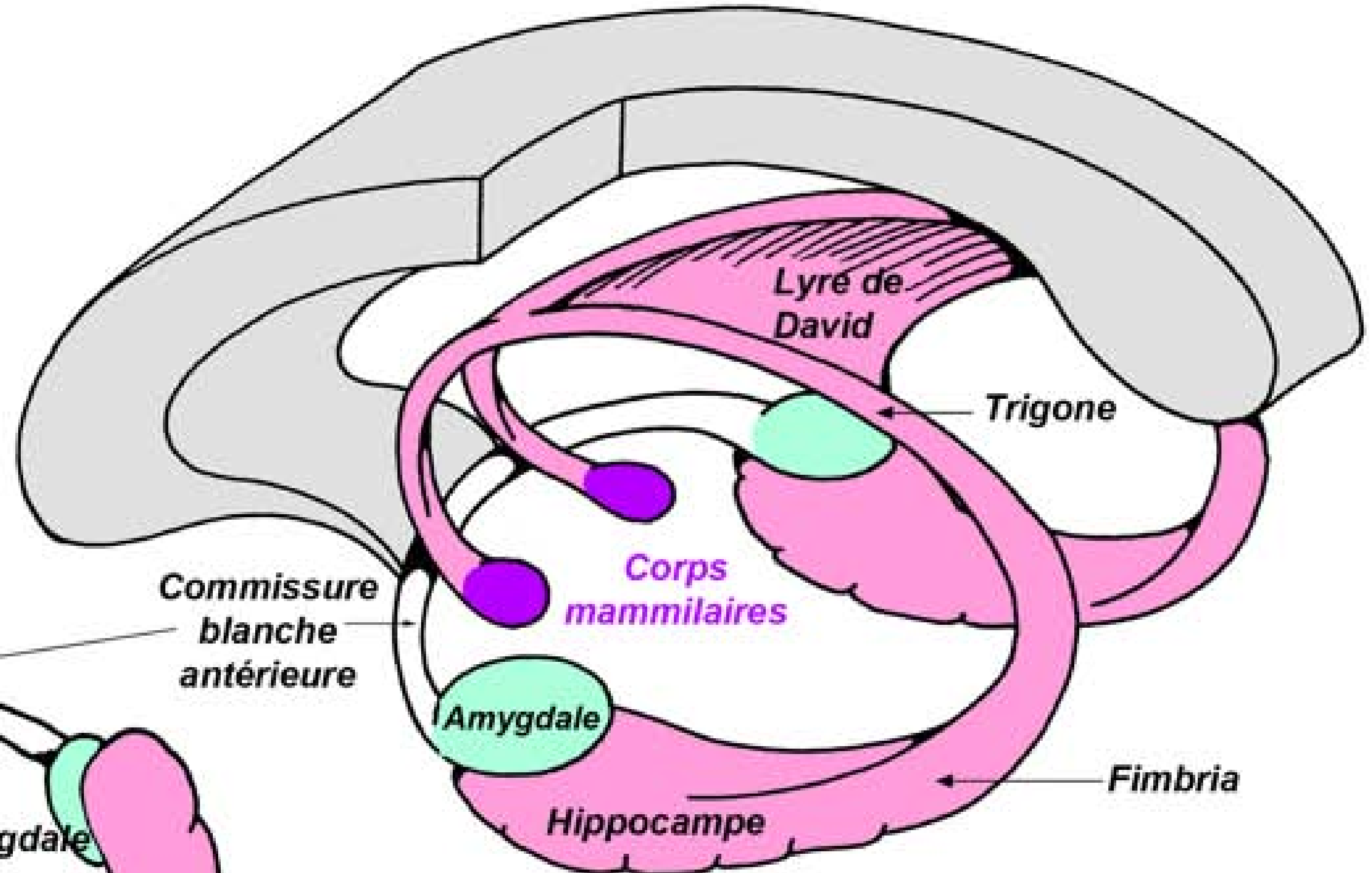
- Neurons (brain & spinal cord)
- Ependymal cells
- Glial cells:
  - Oligodendrocytes
  - astrocytes

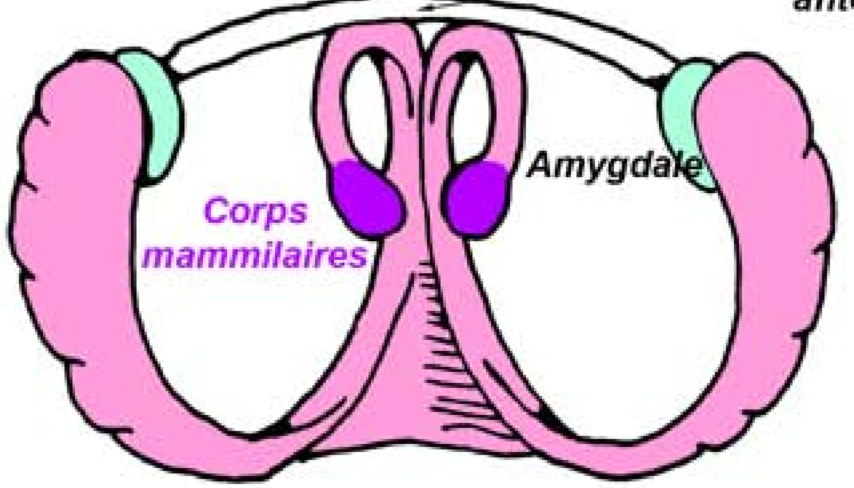


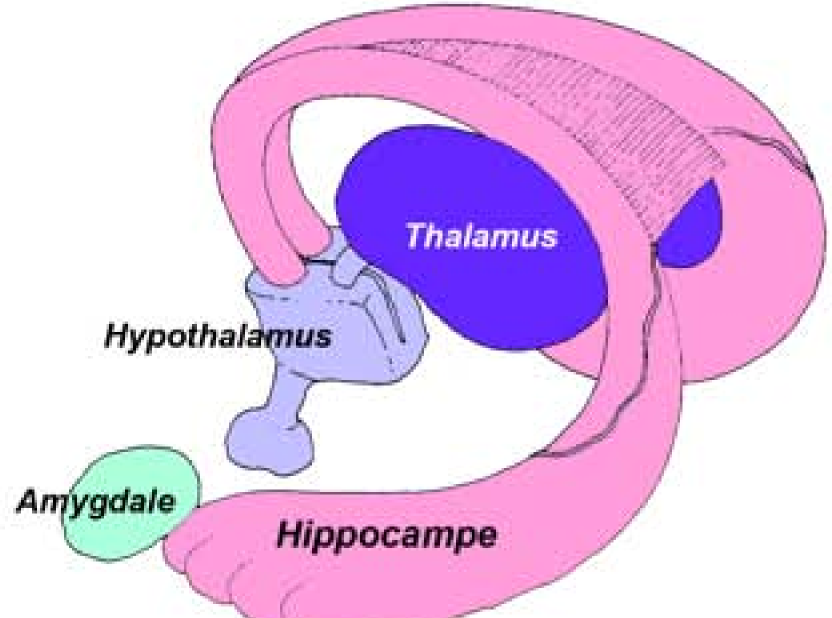
Hippocampus and limbic system

Limbic system



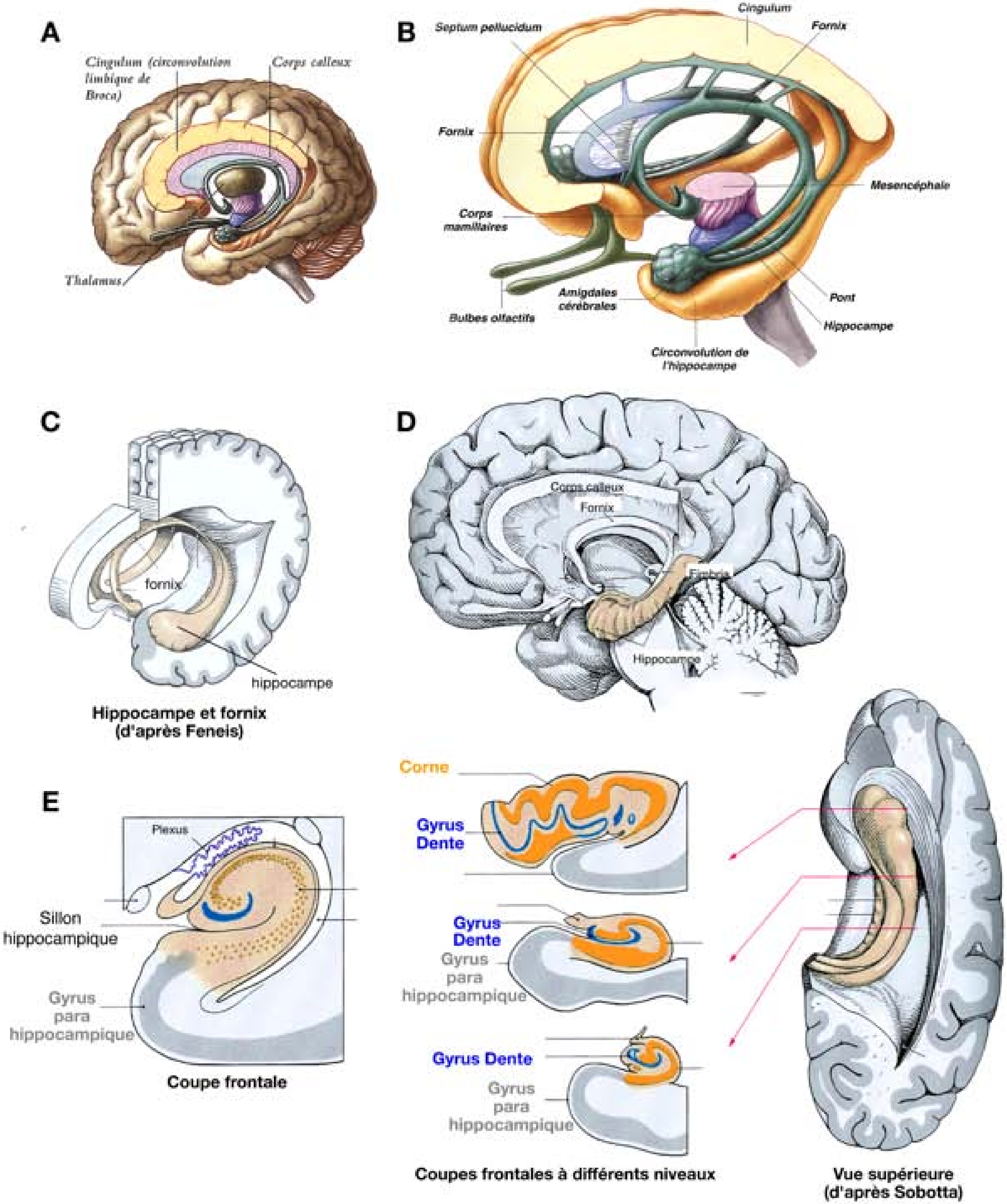






Structure	Component part
Limbic association cortex	Orbitofrontal
	Cingulate
	Entorhinal
	Temporal pole
	Perirhinal
	Parahippocampal
Hippocampal formation	Hippocampus (Ammon's horn)
	Subiculum
	Dentate gyrus
Amygdala	Corticomedial
	Basolateral
	Central nucleus[1]
Ventral striatum	Nucleus accumbens
	Olfactory tubercle
	Ventromedial caudate and putamen
Thalamus	Anterior nucleus
	Medial dorsal nucleus
	Midline nuclei
Hypothalamus	Mammillary nuclei
	Ventromedial nucleus
	Lateral hypothalamic area
Epithalamus[2]	Habenula

Hippocampus



Hippocampus: A cortical structure in the medial portion of the temporal lobe; in humans, concerned with short-term declarative memory, among many other functions.

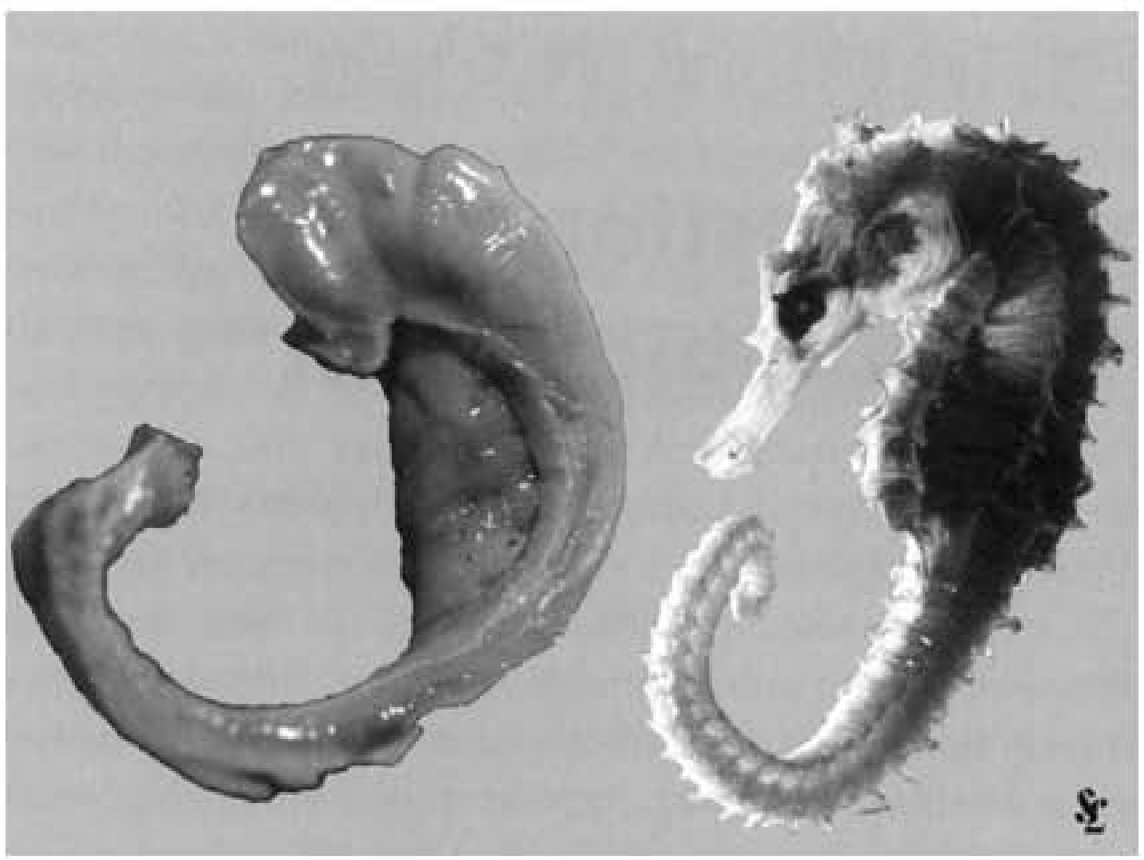
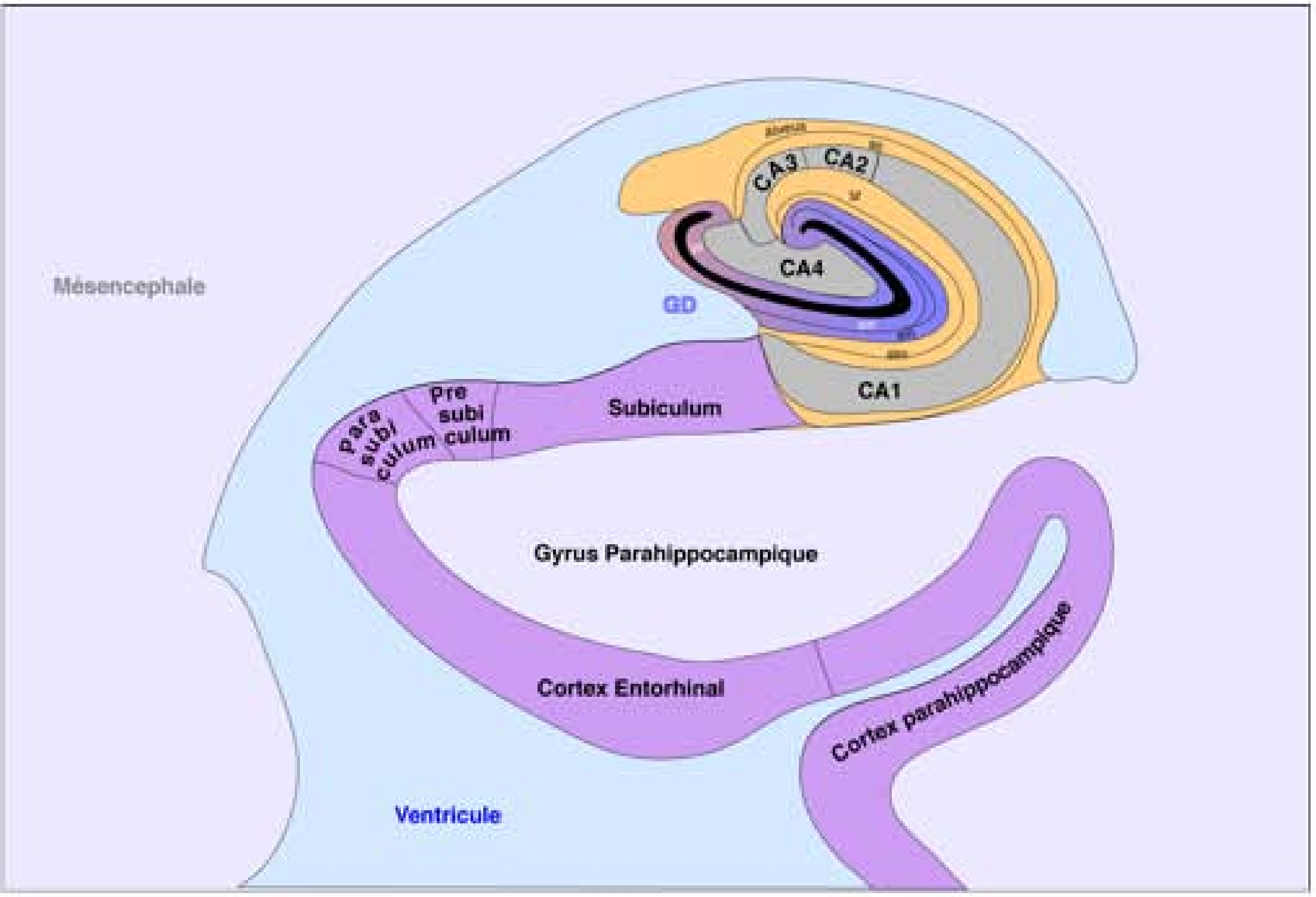
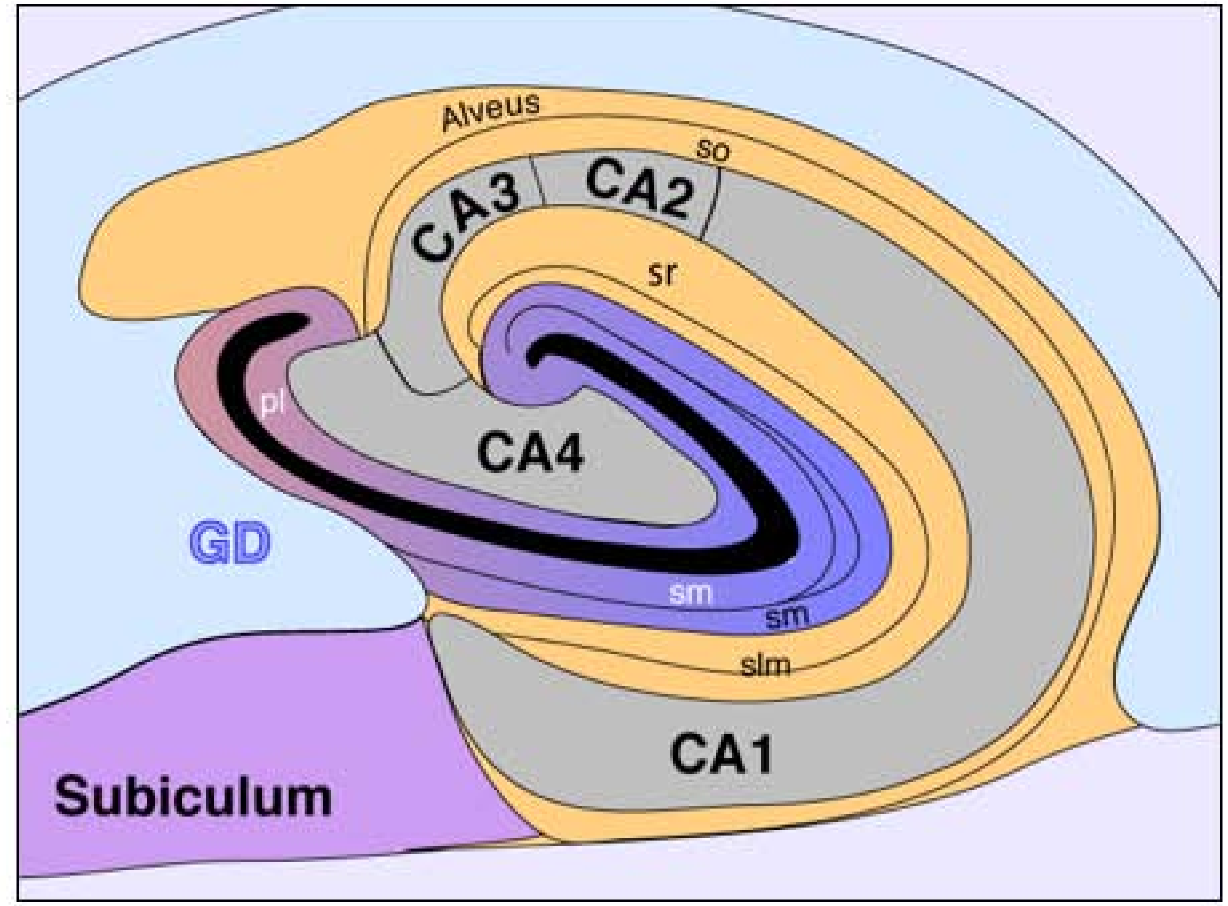
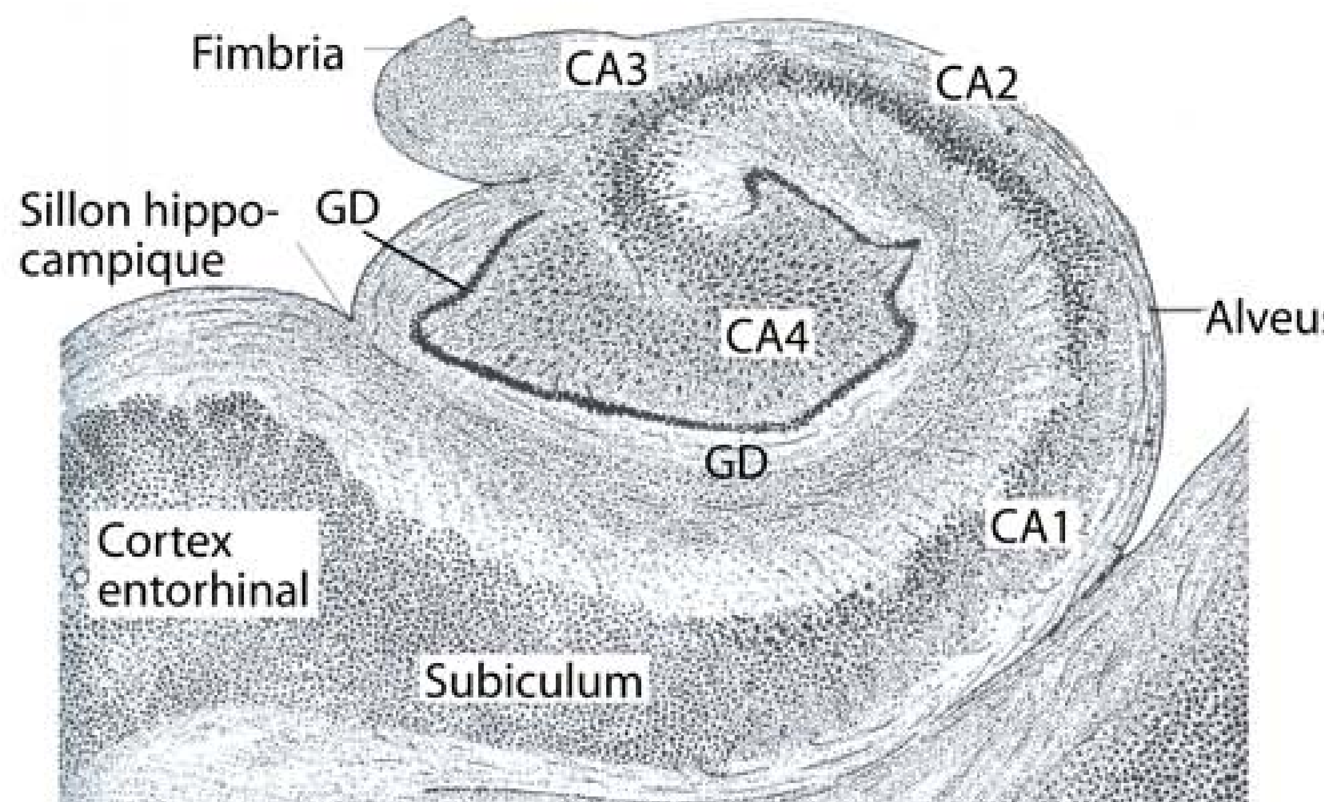


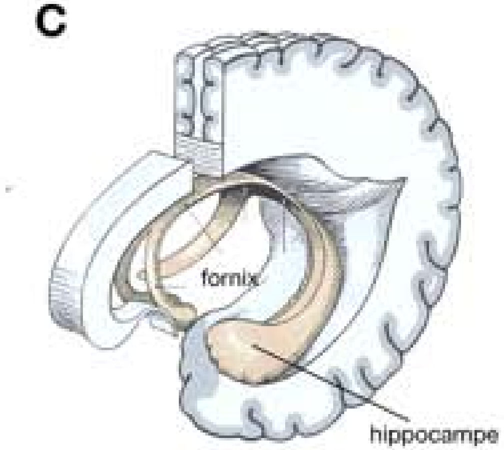
Figure 2–1. Human hippocampus dissected free (*left*) and compared to a specimen of *Hippocampus leria* (*right*). (*Source:* Courtesy of Professor Laszlo Seress, University of Pecs.)







C



Hippocampe et fornix
(d'après Feneis)

Coupe frontale

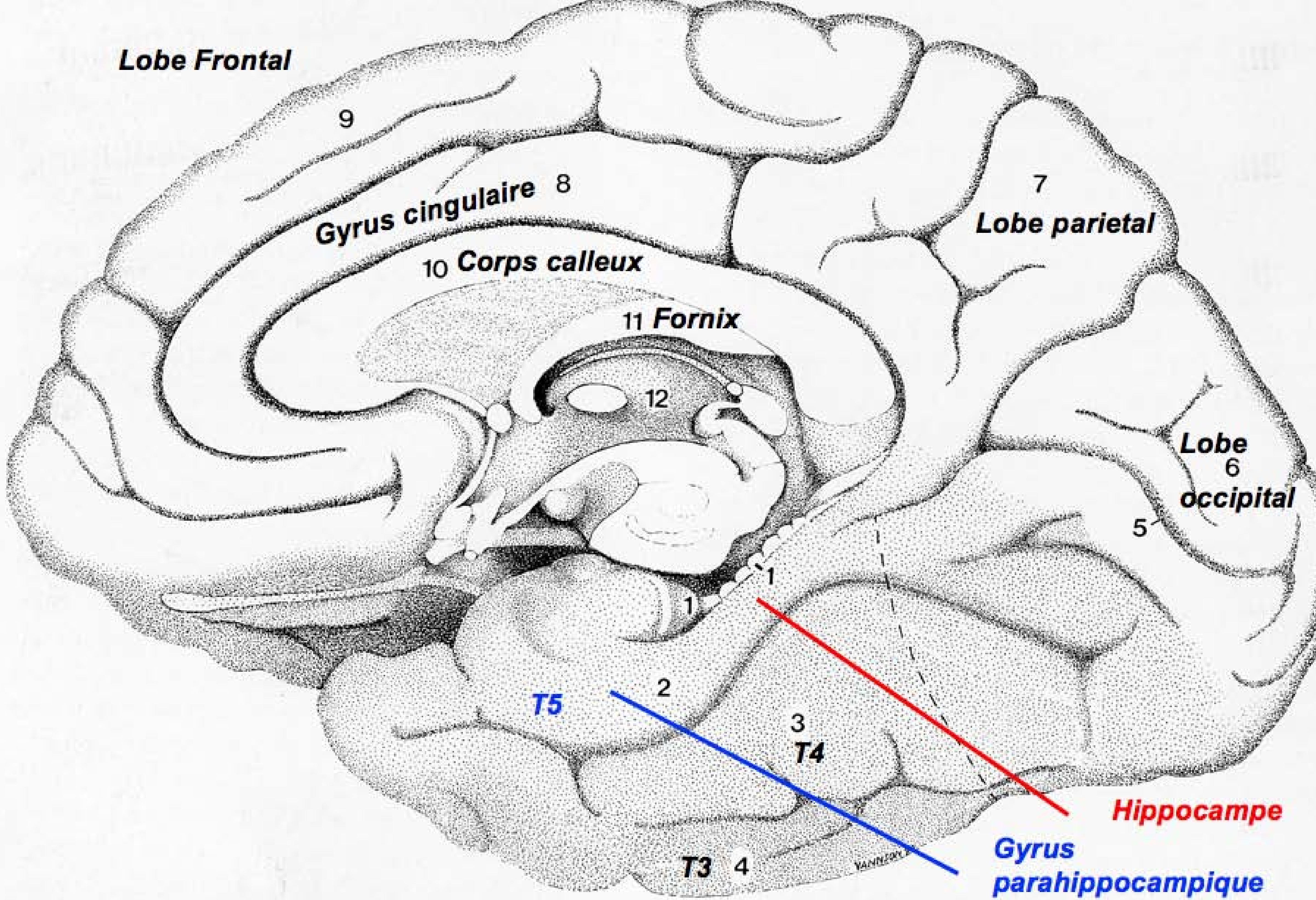
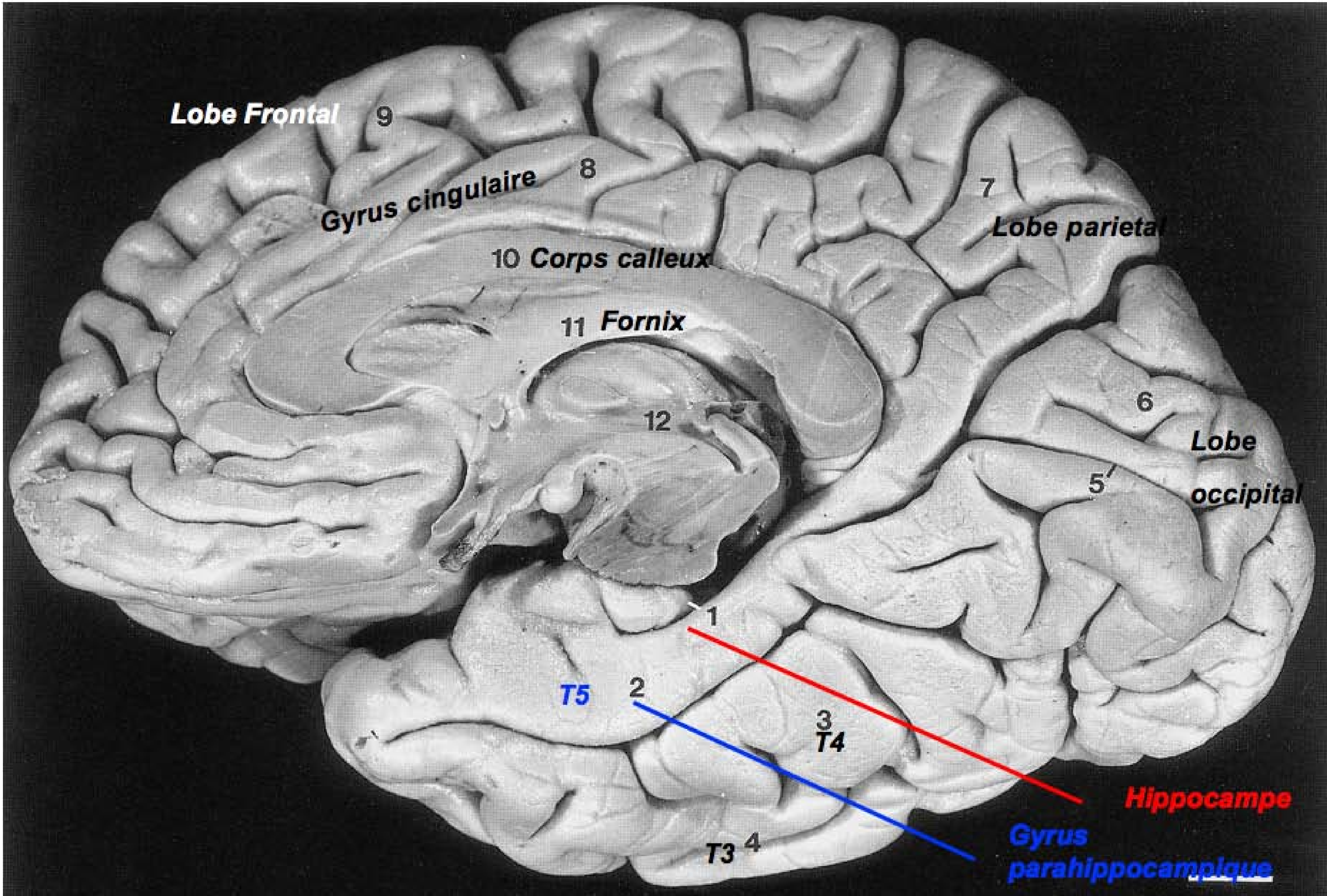


Fig. 1. A Drawing and **B** dissection showing the inferomedial aspect of the right hemisphere. Bar, 10 mm
1, hippocampus, only partly visible on the inferomedial surface of the temporal lobe; 2, parahippocampal gyrus (T5); 3, fusiform gyrus (T4); 4, inferior temporal gyrus (T3); 5, calcarine sulcus; 6, occipital lobe (cuneus); 7, parietal lobe, medial aspect (precuneus); 8, cingulate gyrus; 9, frontal lobe, medial aspect (superior frontal gyrus); 10, corpus callosum; 11, fornix; 12, third ventricle


Lobe Frontal
9
8
Gyrus cingulaire
7
Lobe parietal
10 Corps calleux
11 Fornix
12
6
Lobe
5
occipital
1
T5
2
3
T4
Hippocampe
Gyrus
parahippocampique
T3
4

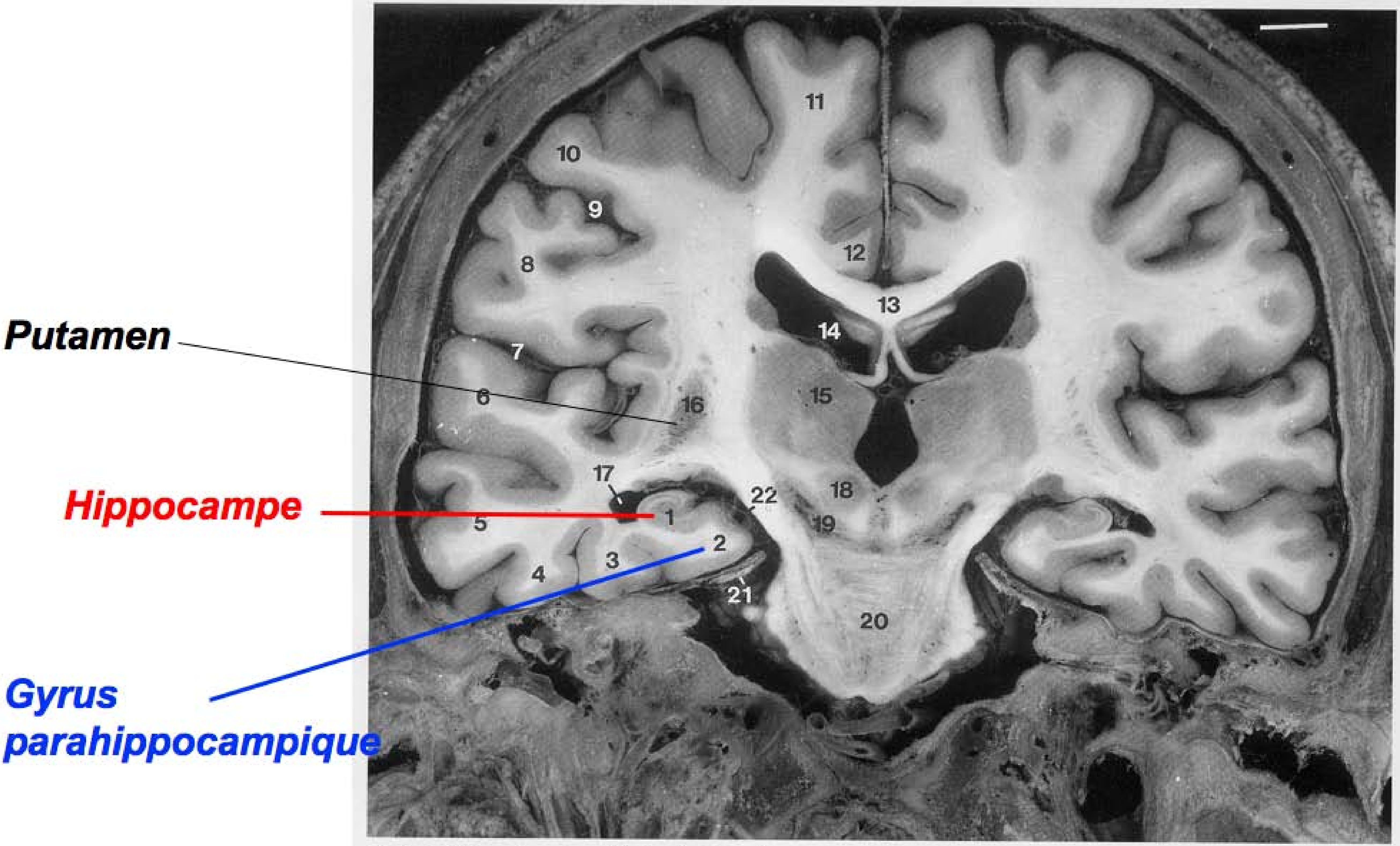


Fig. 2. A, B Coronal section of the brain. **A** Head section. Bar, 10 mm. **B** MRI view, T[1]-weighted image
1, hippocampus; **2**, parahippocampal gyrus; **3**, fusiform gyrus; **4**, inferior temporal gyrus; **5**, middle temporal gyrus; **6**, superior temporal gyrus; **7**, lateral fissure; **8**, postcentral gyrus; **9**, central sulcus; **10**, precentral gyrus; **11**, superior frontal gyrus; **12**, cingulate gyrus; **13**, corpus callosum; **14**, lateral ventricle; **15**, thalamus; **16**, putamen; **17**, temporal (inferior) horn of the lateral ventricle; **18**, red nucleus; **19**, substantia nigra; **20**, pons; **21**, tentorium cerebelli; **22**, ambient cistern

The human hippocampus, Henri M. Duvernoy.

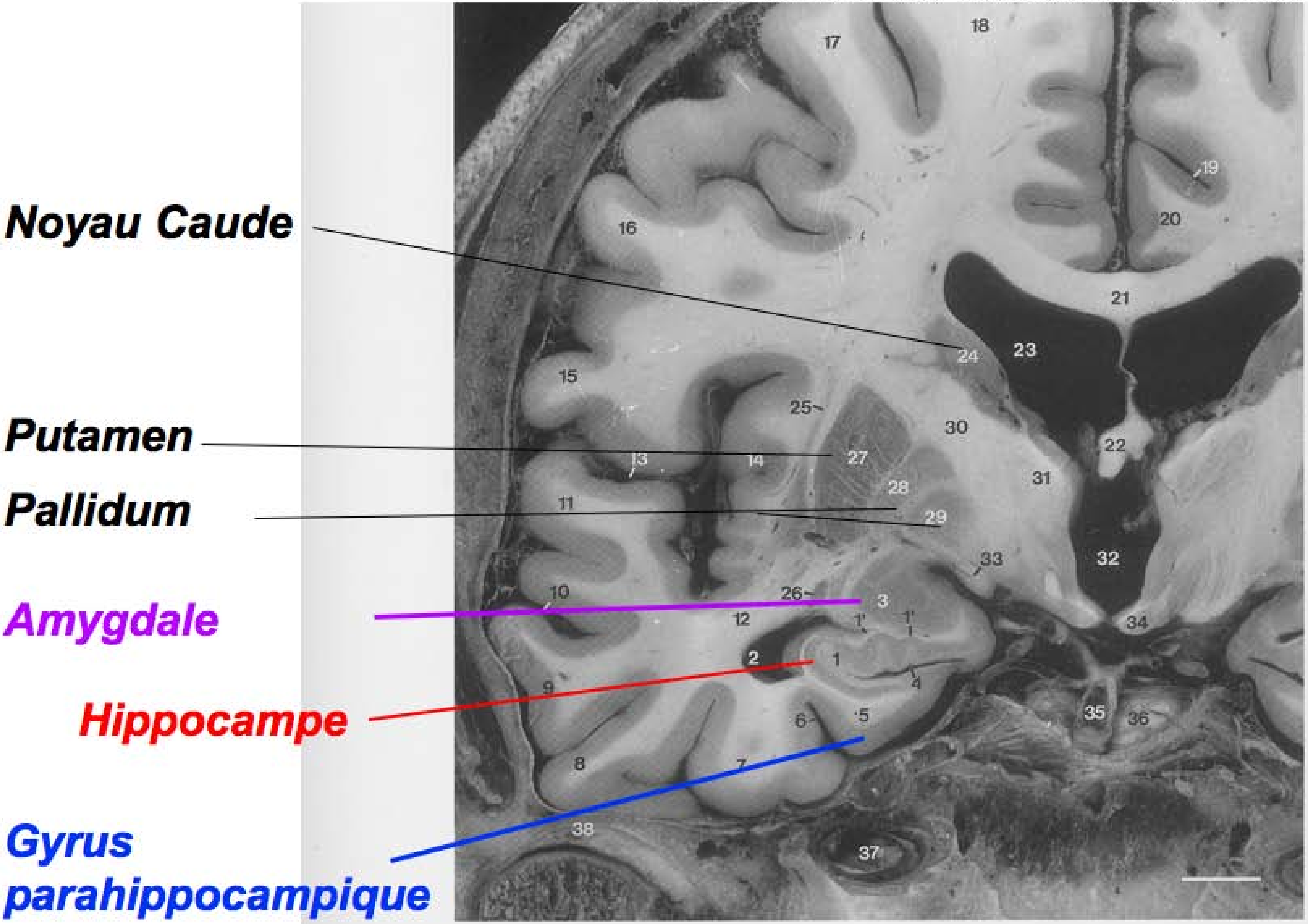


Fig. 84. E Coronal head section. Anterior view of the section. Bar, 10 mm

1, hippocampal head; 1′, internal digitations (digitationes hippocampi); 2, temporal (inferior) horn of the lateral ventricle; 3, amygdala; 4, uncal sulcus; 5, parahippocampal gyrus; 6, collateral sulcus; 7, fusiform gyrus; 8, inferior temporal gyrus; 9, middle temporal gyrus; 10, superior temporal sulcus; 11, superior temporal gyrus; 12, temporal stem; 13, lateral fissure; 14, insula; 15, postcentral gyrus; 16, precentral gyrus; 17, middle frontal gyrus; 18, superior frontal gyrus; 19, cingulate sulcus; 20, cingulate gyrus; 21, corpus callosum; 22, fornix; 23, lateral ventricle; 24, caudate nucleus; 25, claustrum; 26, tail of caudate nucleus; 27, putamen; 28, globus pallidus, lateral part; 29, globus pallidus, medial part; 30, internal capsule, posterior limb; 31, ventral anterior thalamic nucleus; 32, third ventricle; 33, optic tract; 34, mamillary body; 35, basilar artery; 36, pons; 37, internal carotid artery; 38, temporomandibular joint

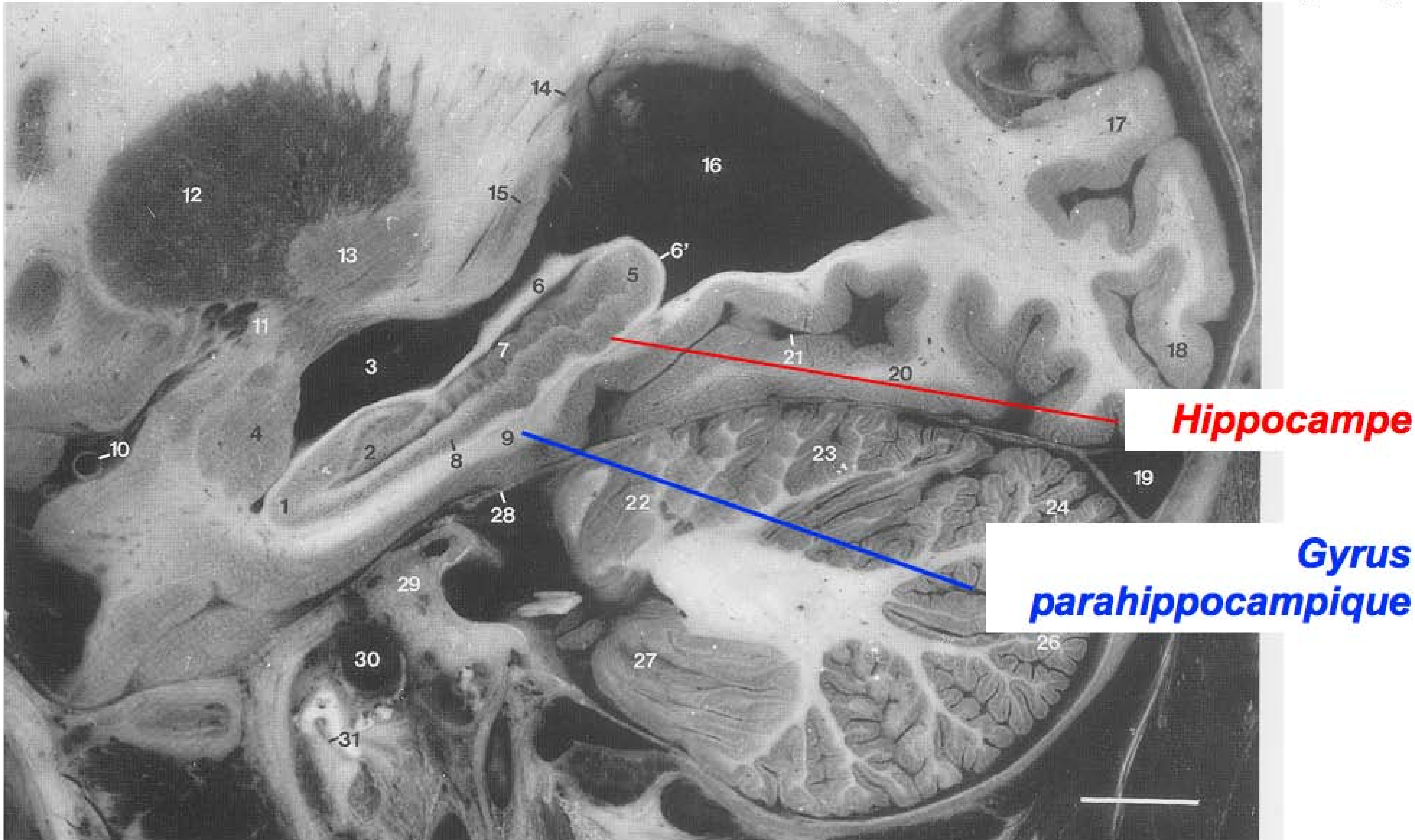
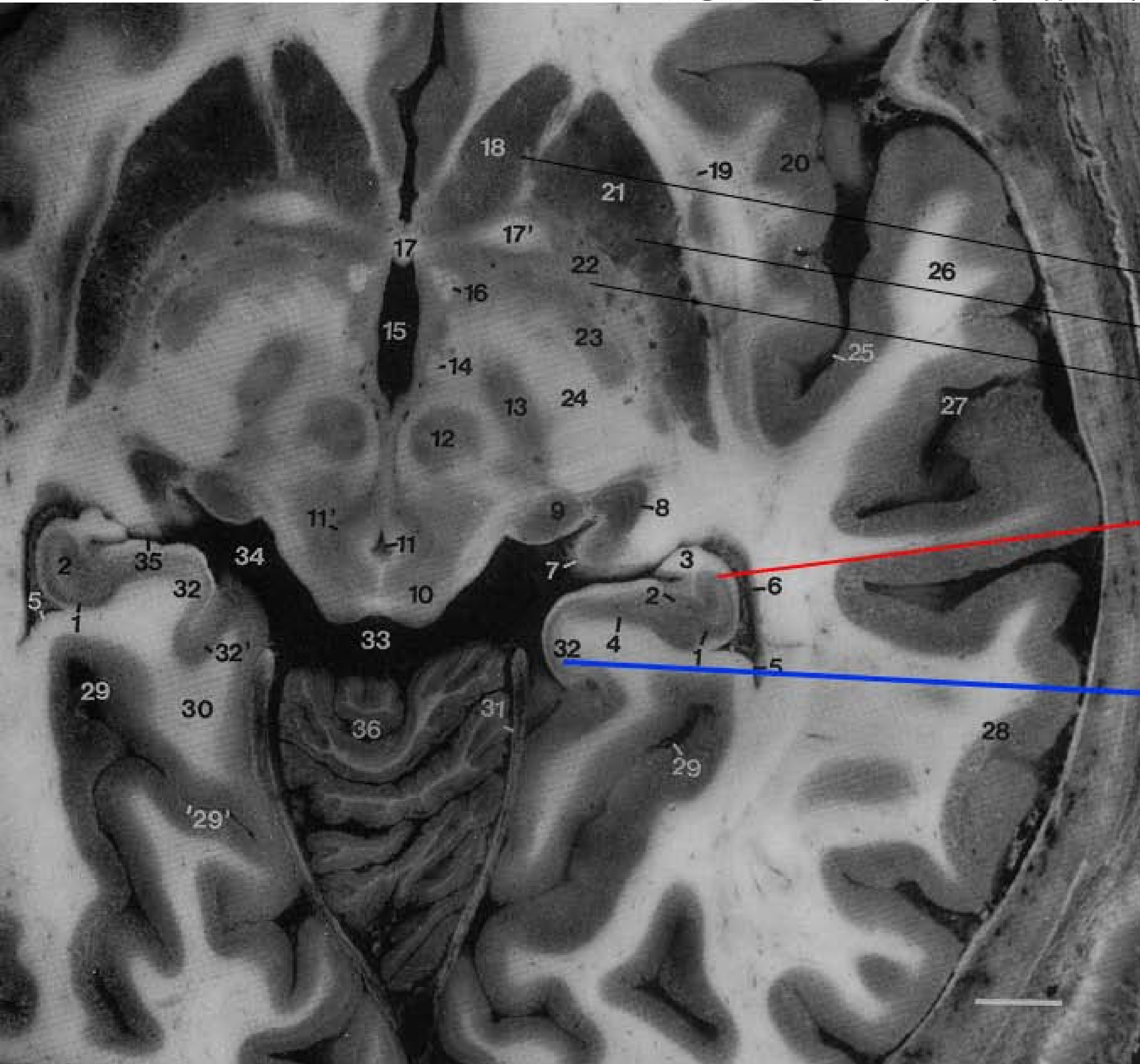
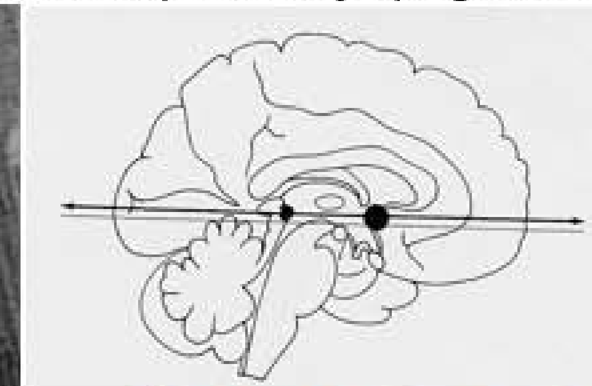


Fig. 97. F Head section. **Bar**, 10 mm

1, hippocampal head, cornu Ammonis; **2**, hippocampal head, gyrus dentatus; **3**, temporal (inferior) horn of the lateral ventricle; **4**, amygdala; **5**, hippocampal body, cornu Ammonis; **6**, fimbria; **6'**, alveus; **7**, margo denticulatus (gyrus dentatus); **8**, subiculum; **9**, parahippocampal gyrus; **10**, middle cerebral artery; **11**, anterior commissure, lateral part; **12**, putamen; **13**, globus pallidus, lateral part; **14**, caudate nucleus; **15**, pulvinar; **16**, lateral ventricle; **17**, middle occipital gyrus; **18**, inferior occipital gyrus; **19**, transverse sinus; **20**, fusiform gyrus; **21**, collateral sulcus; **21'**, anterior calcarine sulcus; **21"**, calcar avis; **22**, quadrangular lobule; **23**, simple lobule; **24**, superior semilunar lobule; **25**, horizontal fissure; **26**, inferior semilunar lobule; **27**, biventer lobule; **28**, tentorium cerebelli; **29**, temporal, petrous part; **30**, internal carotid artery; **31**, auditory tube





1, hippocampal body, cornu Ammonis; 2, hippocampal body, gyrus dentatus; 3, fimbria; 4, subiculum; 5, collateral eminence; 6, temporal (inferior) horn of the lateral ventricle; 7, pulvinar; 8, lateral geniculate body; 9, medial geniculate body; 10, superior colliculus; 11, cerebral aqueduct; 11′, periaqueductal grey matter; 12, red nucleus; 13, substantia nigra; 14, mamillothalamic tract; 15, third ventricle; 16, column of fornix; 17, anterior commissure, medial part; 17′, anterior commissure, lateral part; 18, caudate nucleus; 19, claustrum; 20, insula; 21, putamen; 22, globus pallidus, lateral part; 23, globus pallidus, medial part; 24, internal capsule, posterior limb; 25, lateral fissure; 26, superior temporal gyrus; 27, superior temporal sulcus; 28 middle temporal gyrus; 29 collateral sulcus; 29′, lingual sulcus; 30, lingual gyrus; 31, tentorium cerebelli; 32, parahippocampal gyrus; 32′, anterior calcarine sulcus; 33, quadrigeminal cistern; 34, ambient cistern; 35, wing of ambient cistern; 36, culmen

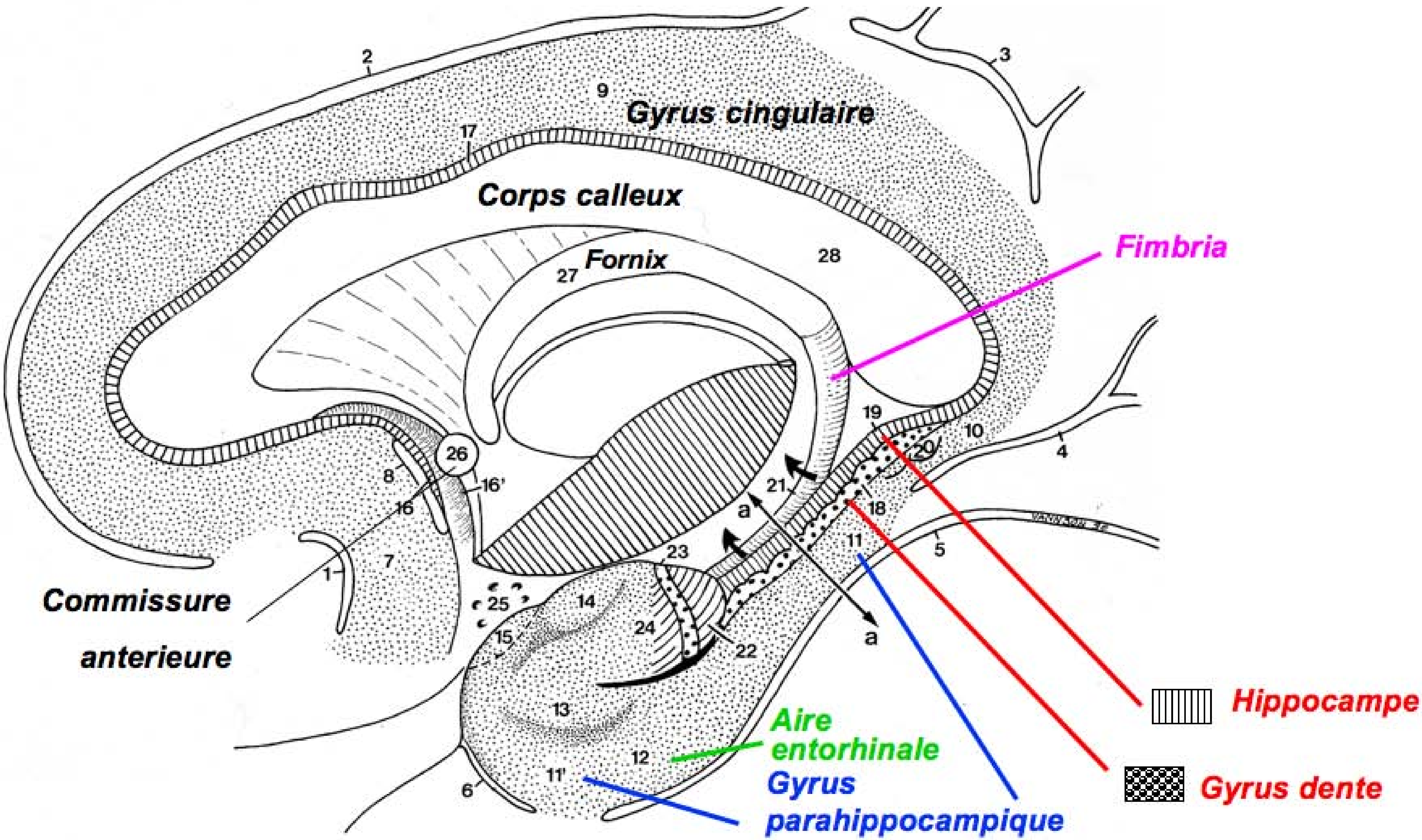


Fig. 4. A Drawing and **B** dissection showing a sagittal section, right hemisphere. The limbic lobe is separated from the isocortex by the limbic fissure and may be divided into two gyri: the limbic and intralimbic gyri. The line **a**–**a** indicates the plane of the section on Fig. 5. Bar, 7.7 mm
Limbic fissure: **1**, anterior paraolfactory sulcus (subcallosal sulcus); **2**, cingulate sulcus; **3**, subparietal sulcus; **4**, anterior calcarine sulcus; **5**, collateral sulcus; **6**, rhinal sulcus. Limbic gyrus: **7**, subcallosal gyrus; **8**, posterior paraolfactory sulcus; **9**, cingulate gyrus; **10**, isthmus; **11**, parahippocampal gyrus, posterior part; **11′**, parahippocampal gyrus, anterior part (piriform lobe). Piriform lobe: **12**, entorhinal area; **13**, ambient gyrus; **14**, semilunar gyrus; **15**, prepiriform cortex. Intralimbic gyrus: **16**, prehippocampal rudiment; **16′**, paraterminal gyrus; **17**, indusium griseum. Hippocampus: **18**, gyrus dentatus; **19**, cornu Ammonis; **20**, gyri of Andreas Retzius; **21**, fimbria (displaced upwards, arrows); **22**, uncal apex; **23**, band of Giacomini; **24**, uncinate gyrus; **25**, anterior perforated substance; **26**, anterior commissure; **27**, fornix; **28**, corpus callosum

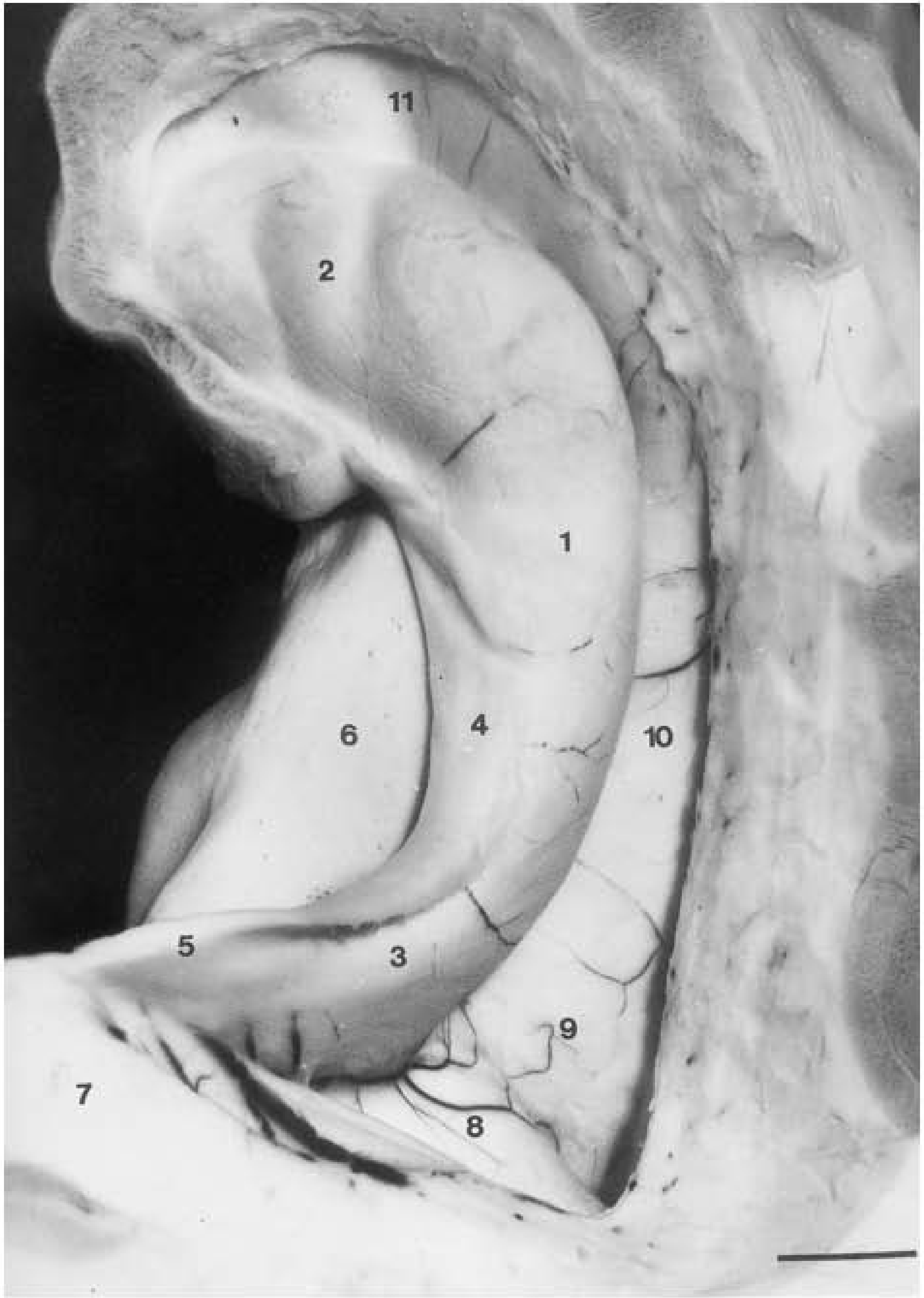


Fig. 3. Intraventricular aspect of the hippocampus. The temporal horn has been opened and the choroid plexuses removed. **Bar,** 6.5 mm
1, hippocampal body; **2,** head and digitationes hippocampi (internal digitations); **3,** hippocampal tail; **4,** fimbria; **5,** crus of fornix; **6,** subiculum; **7,** splenium of the corpus callosum; **8,** calcar avis; **9,** collateral trigone; **10,** collateral eminence; **11,** uncal recess of the temporal horn

The human hippocampus, Henri M. Duvernoy.

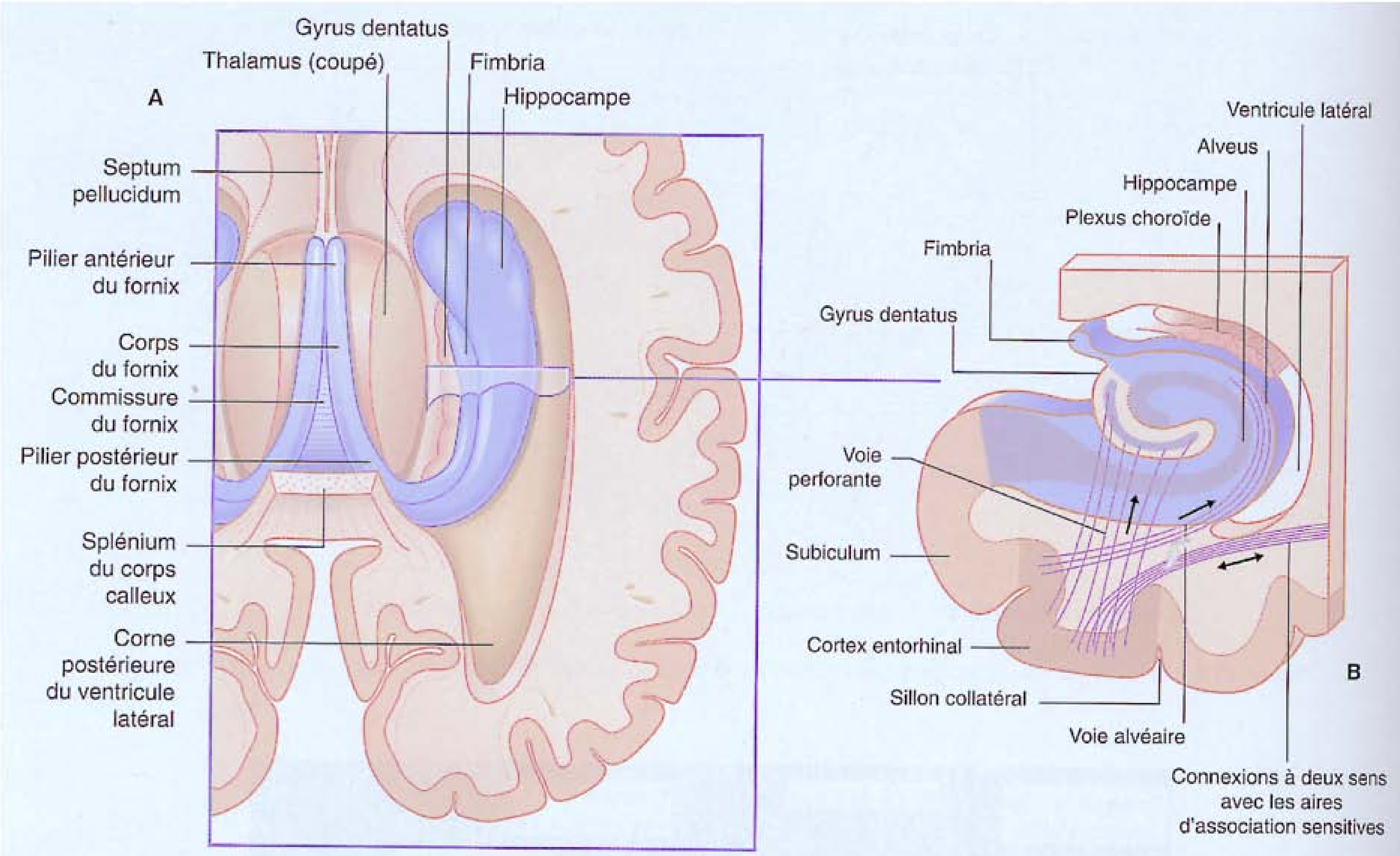
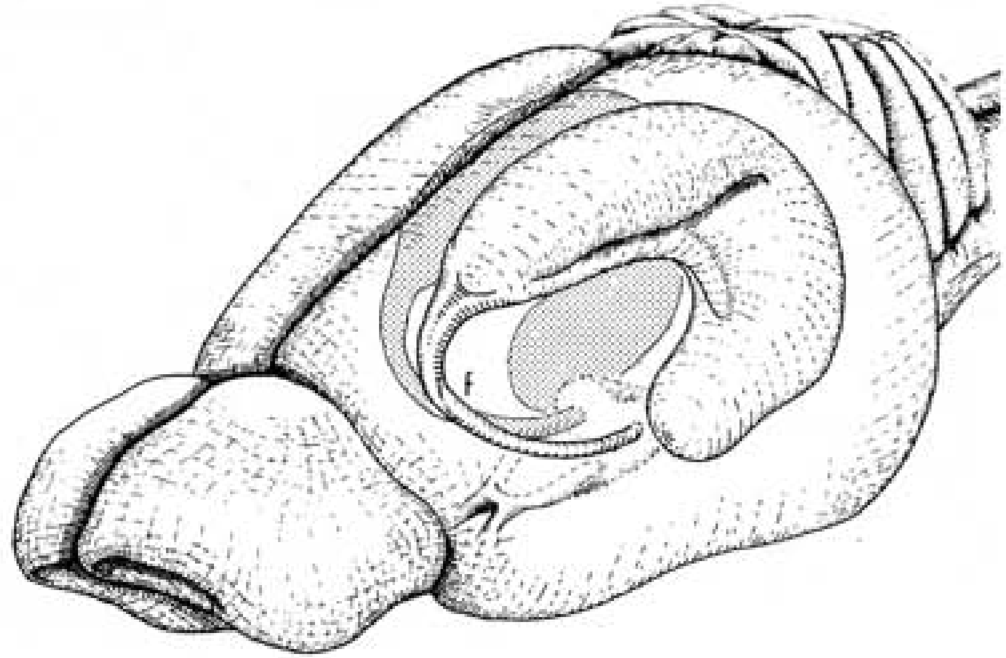
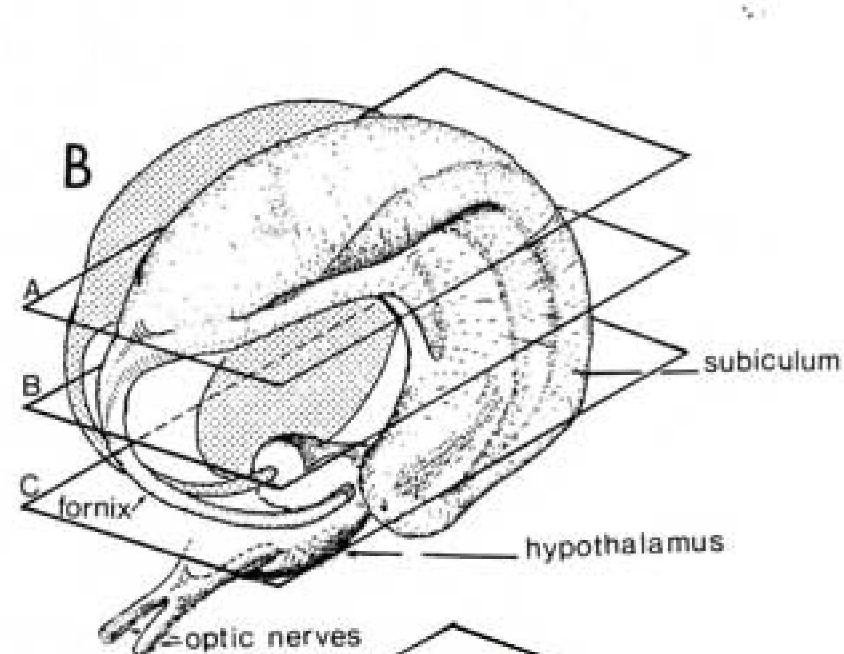
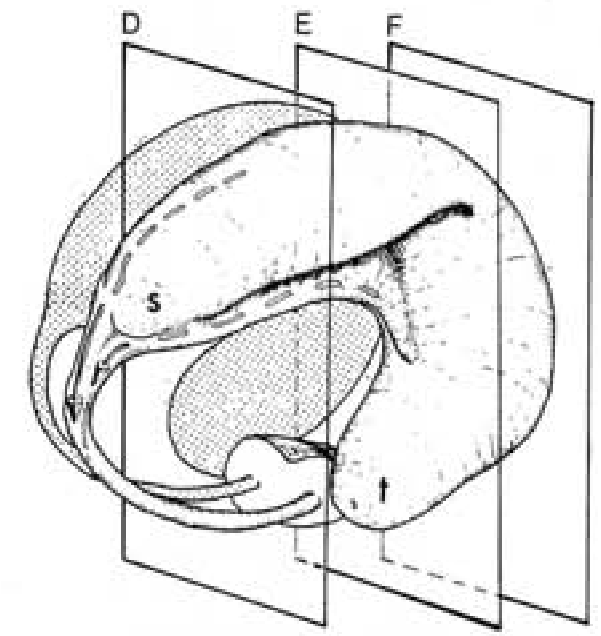
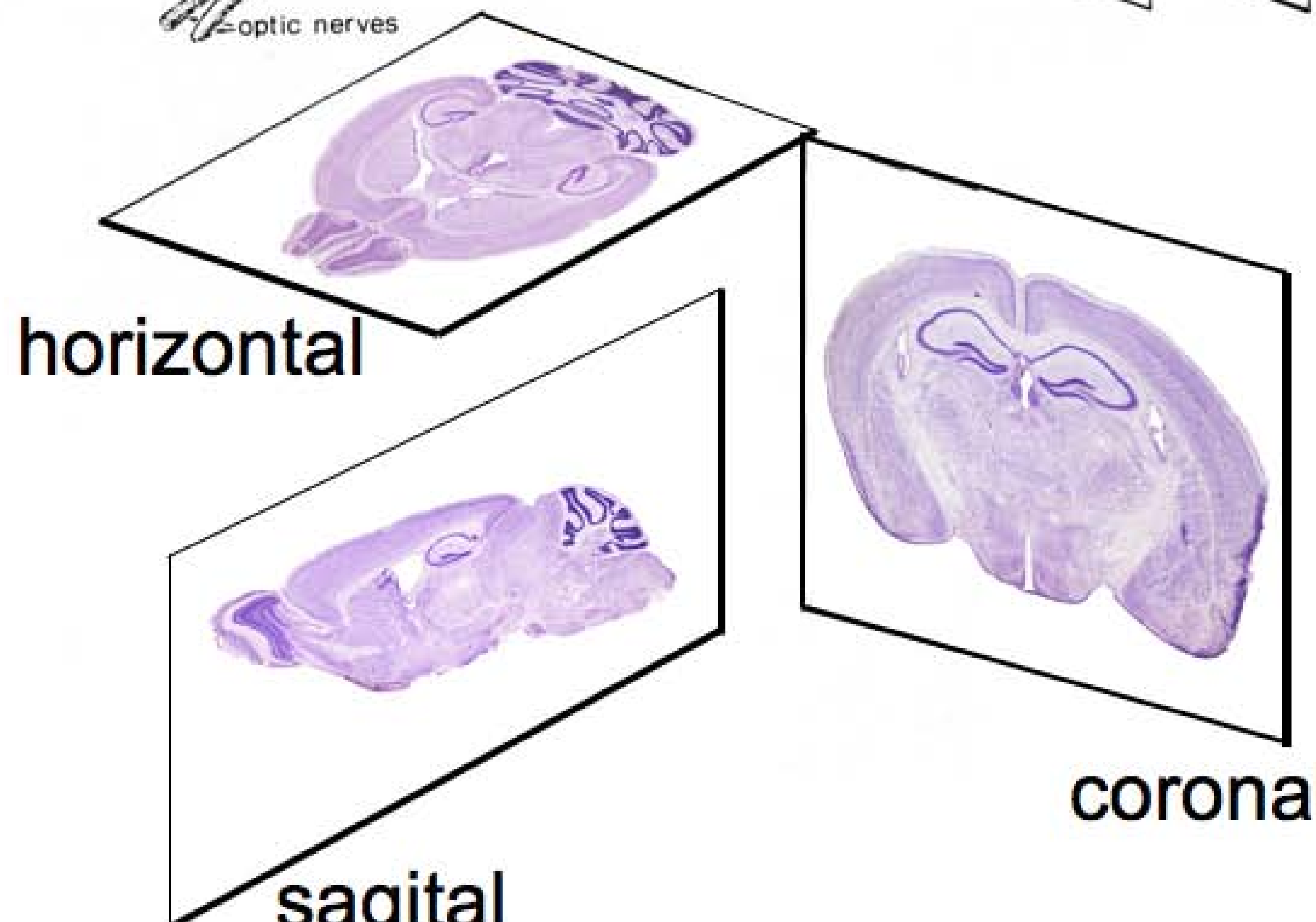


Figure 29.5 Formation hippocampique. **(A)** Vue par au-dessus. **(B)** Grossissement de **A**, montrant le cortex entorhinal et les trois parties composant la formation hippocampique.



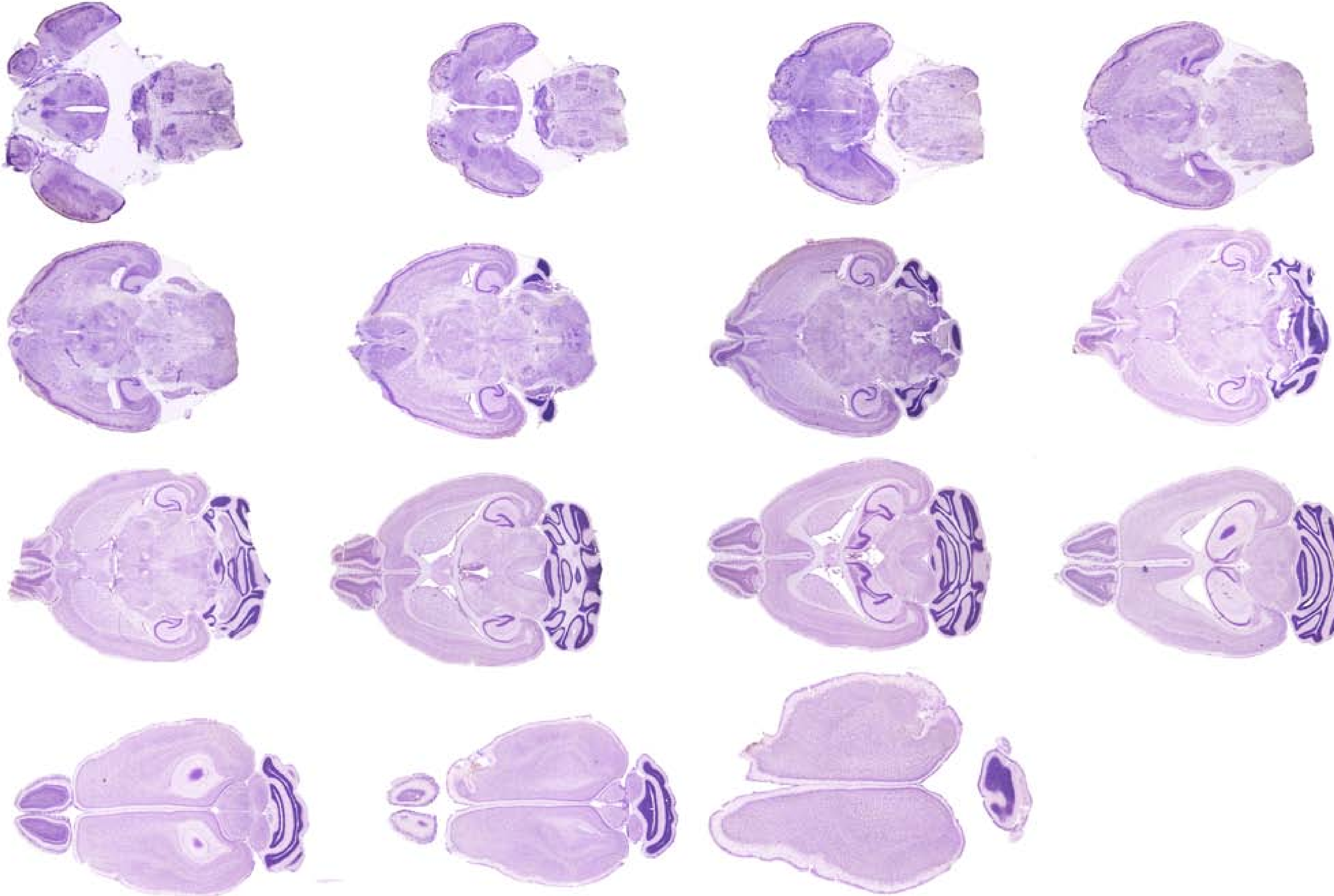




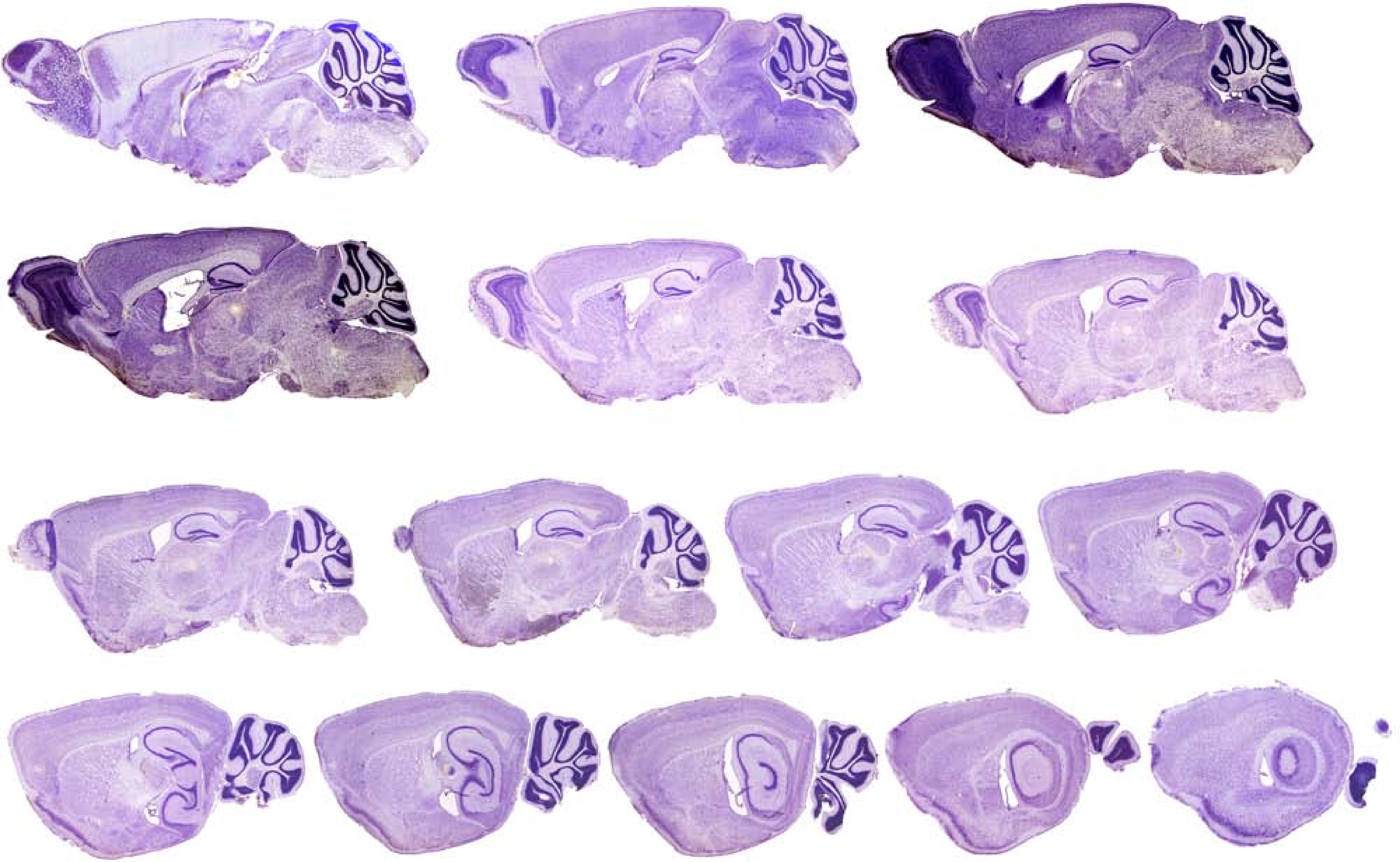


Hippocampal formation,
Amaral and Witter,
in The Rat Nervous System,
Edited by Paxinos, 2001

Horizontal view



Sagital view



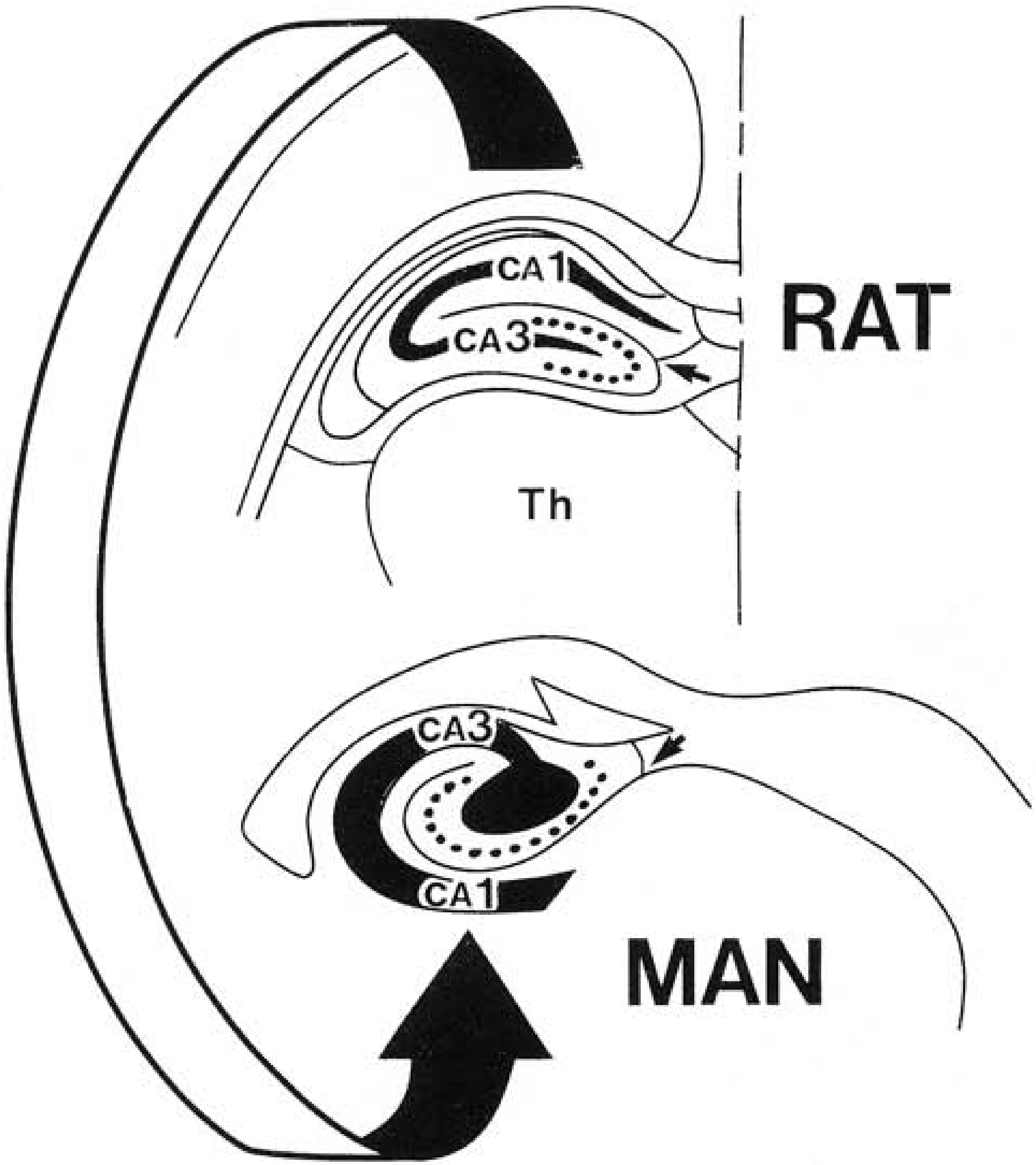
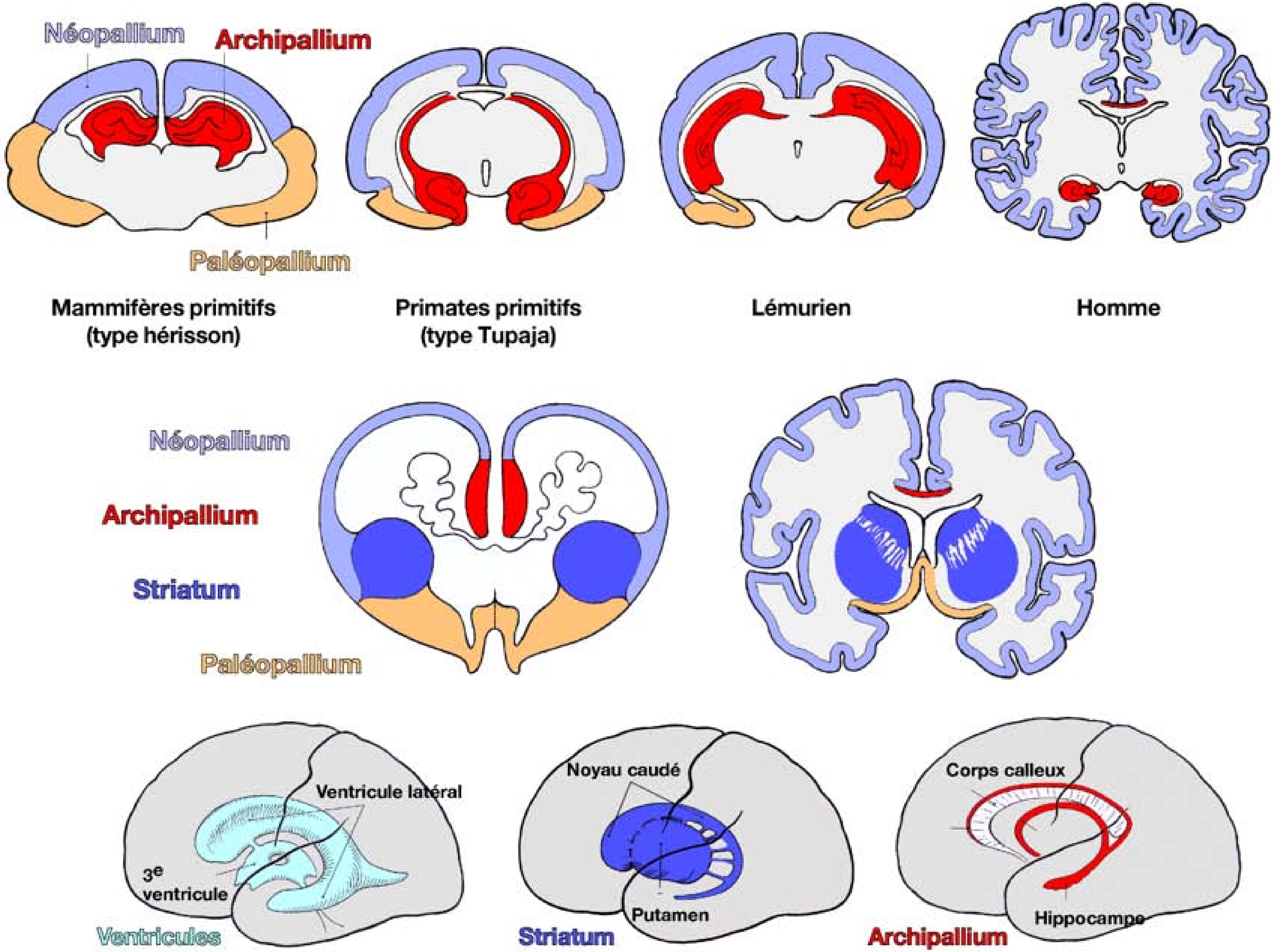
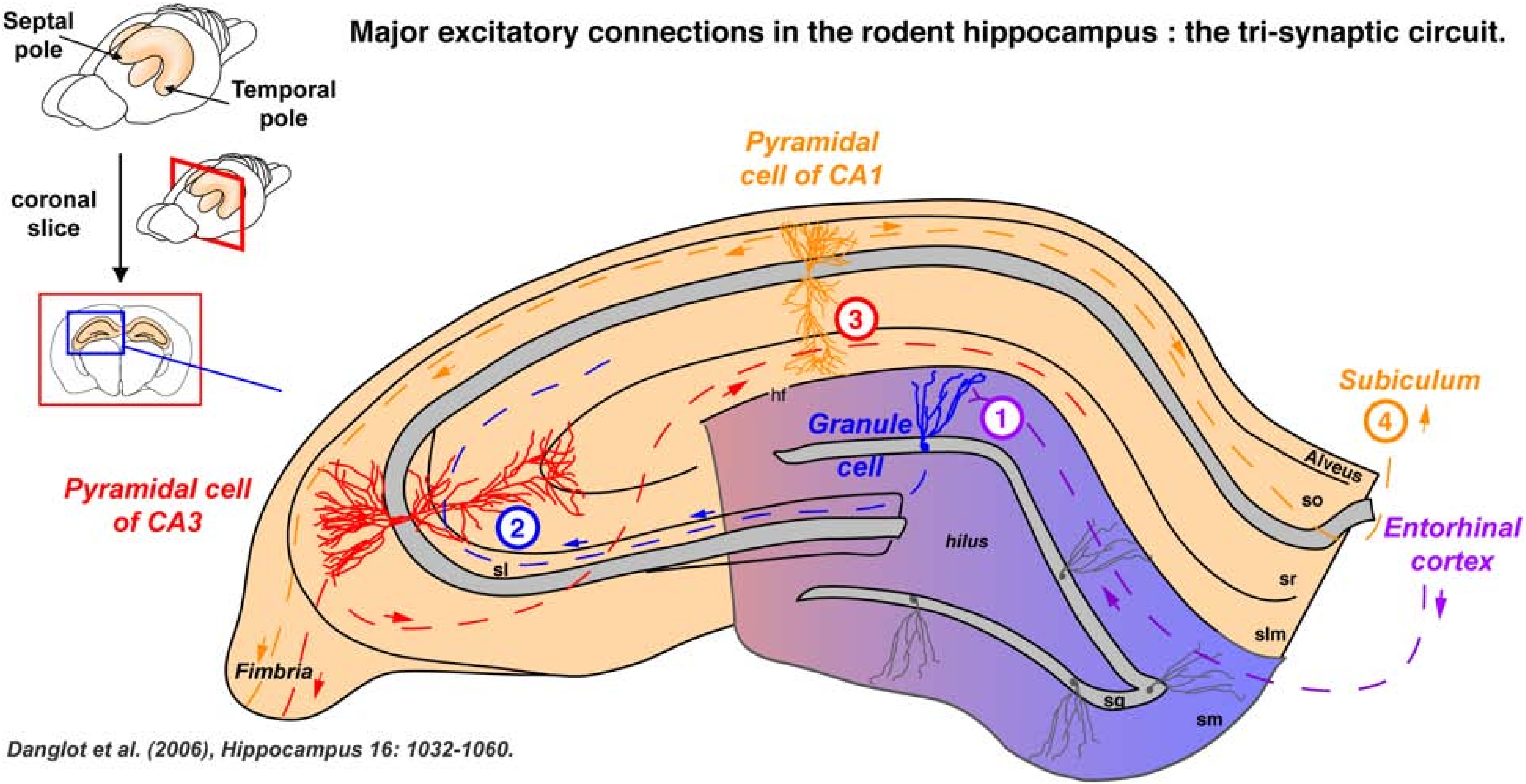


Fig. 6. Site of CA1 and CA3 in rats and humans (see p. 8). **Arrowheads** show the hippocampal sulcus. The **arrow** indicates the inversion of arrangements in the hippocampus in these two species
CA1, superior region; **CA3**, inferior region; **Th**, thalamus

The human hippocampus, Henri M. Duvernoy.


Néopallium
Archipallium
Paléopallium
Mammifères primitifs (type hérisson)
Primates primitifs (type Tupaja)
Lémurien
Homme
Néopallium
Archipallium
Striatum
Paléopallium
Ventricule latéral
3e ventricule
Ventricules
Noyau caudé
Putamen
Striatum
Corps calleux
Hippocampe
Archipallium

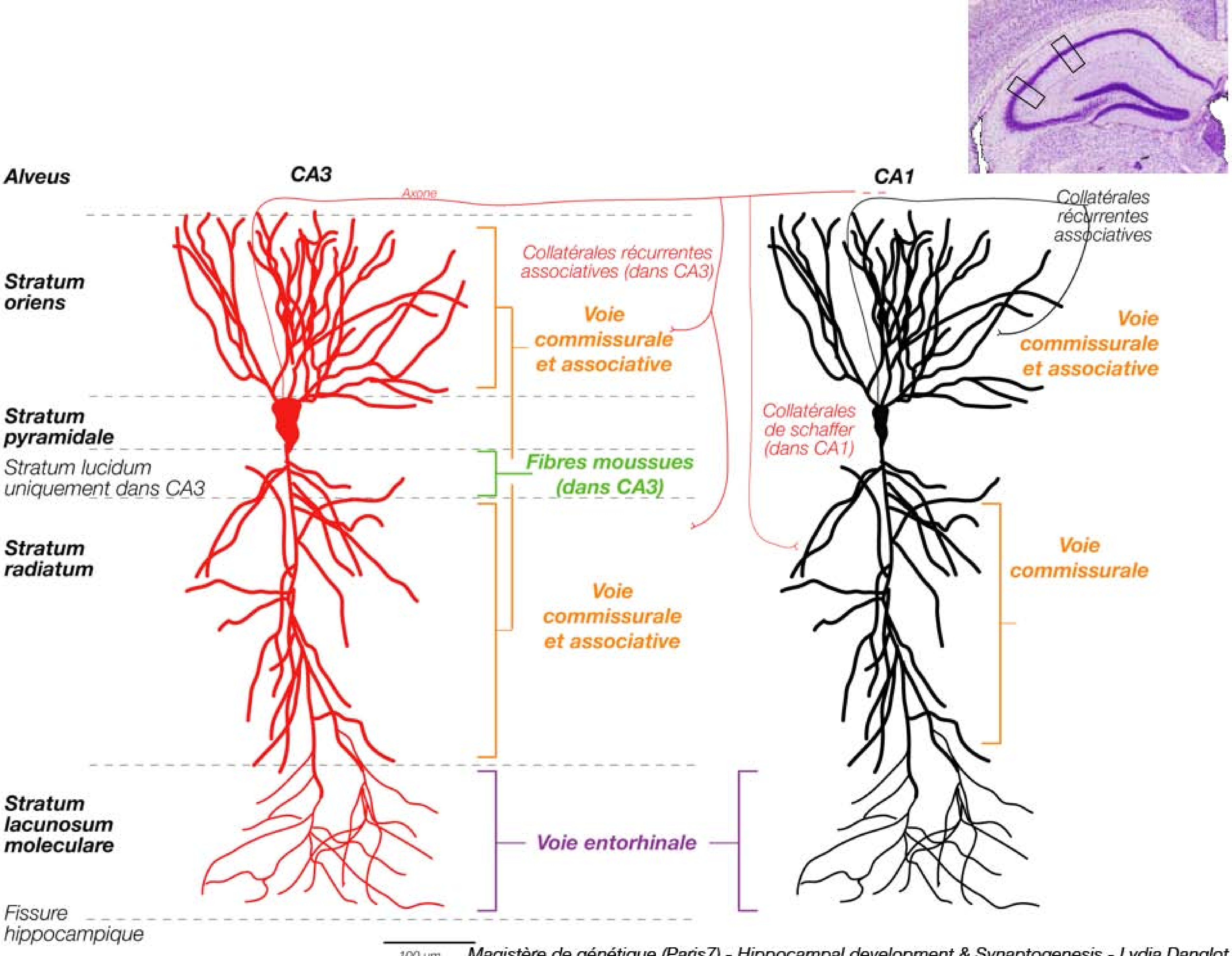
Major excitatory connections in the rodent hippocampus : the tri-synaptic circuit.

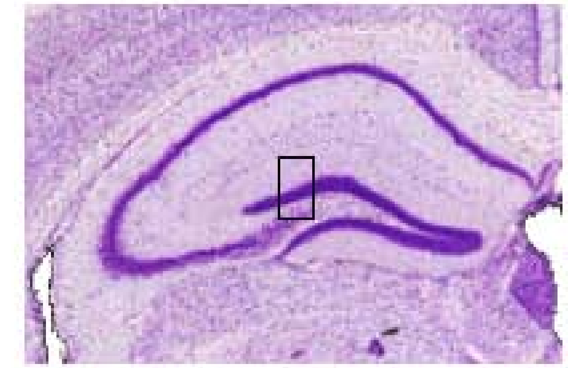


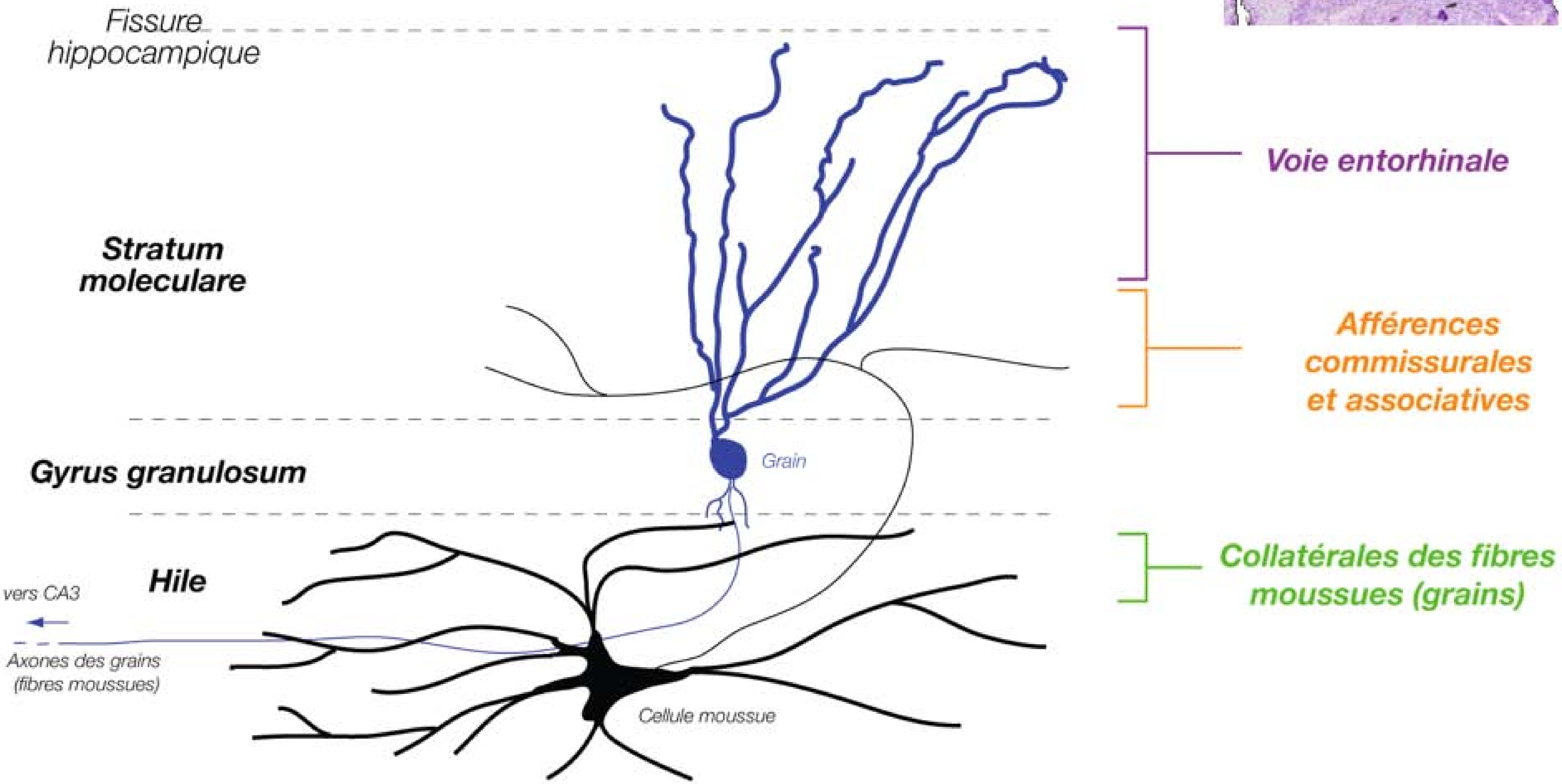
Danglot et al. (2006), Hippocampus 16: 1032-1060.

- 1. Perforant path : axons from the entorhinal cortex innervate granule cells.
- 2. The axons of the granule cells (mossy fibers) innervate pyramidal cells of CA3.
- 3. The axons of the pyramidal cells of CA3 (Schaffer collaterals) innervate pyramidal cells of CA1.
- 4. The axon of the pyramidal cells of CA1 innervate the subiculum and the entorhinal cortex.

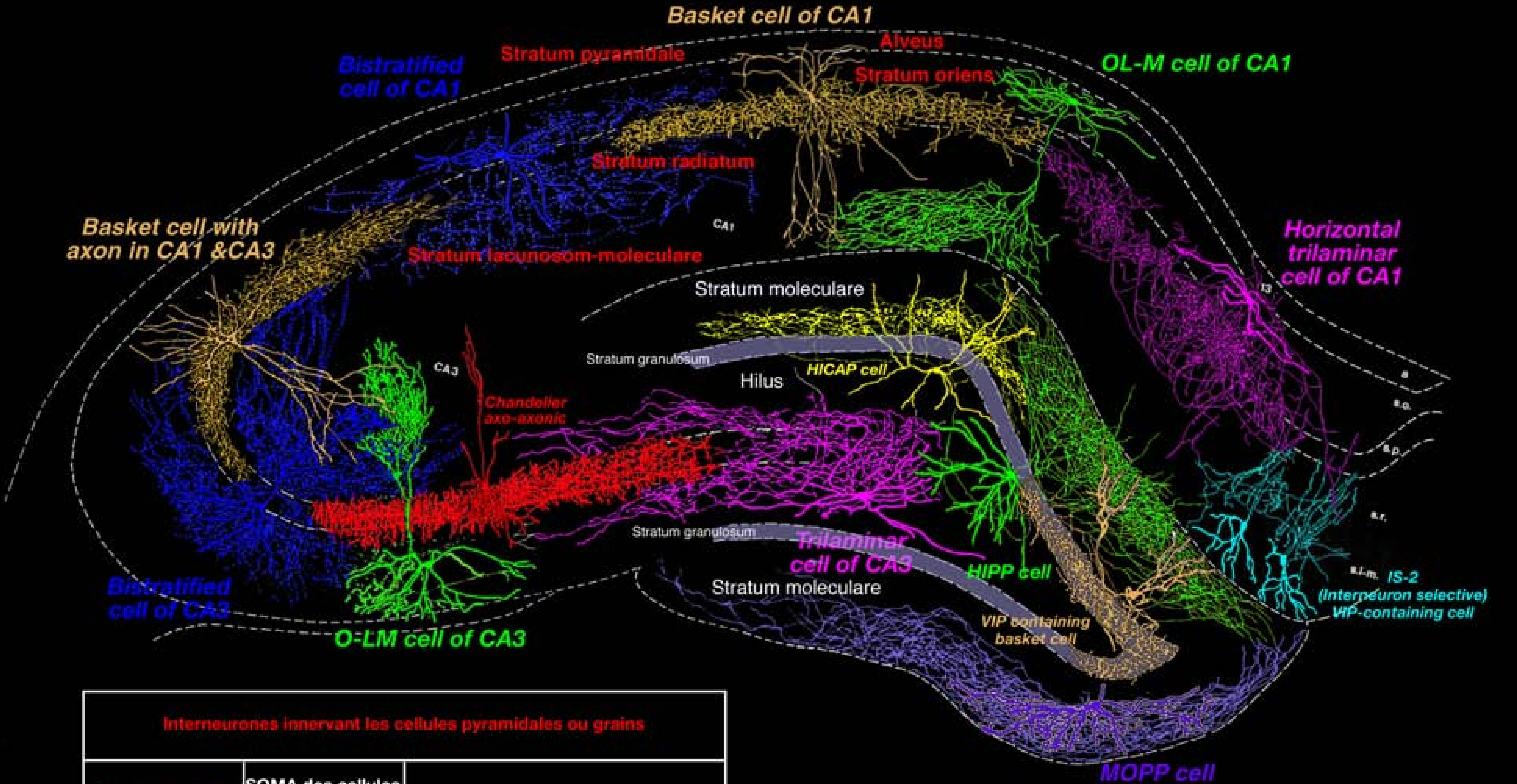
Cells types


Alveus
CA3
CA1
Axone
Collatérales récurrentes associatives (dans CA3)
Collatérales récurrentes associatives
Stratum oriens
Voie commissurale et associative
Voie commissurale et associative
Stratum pyramidale
Collatérales de schaffer (dans CA1)
Stratum lucidum uniquement dans CA3
Fibres moussues (dans CA3)
Stratum radiatum
Voie commissurale
Voie commissurale et associative
Stratum lacunosum moleculare
Voie entorhinale
Fissure hippocampique
100 um




Fissure hippocampique
Stratum moleculare
Gyrus granulosum
Hile
vers CA3
Axones des grains (fibres moussues)
Grain
Cellule moussue
Voie entorhinale
Afférences commissurales et associatives
Collatérales des fibres moussues (grains)

Classification des interneurones hippocampiques

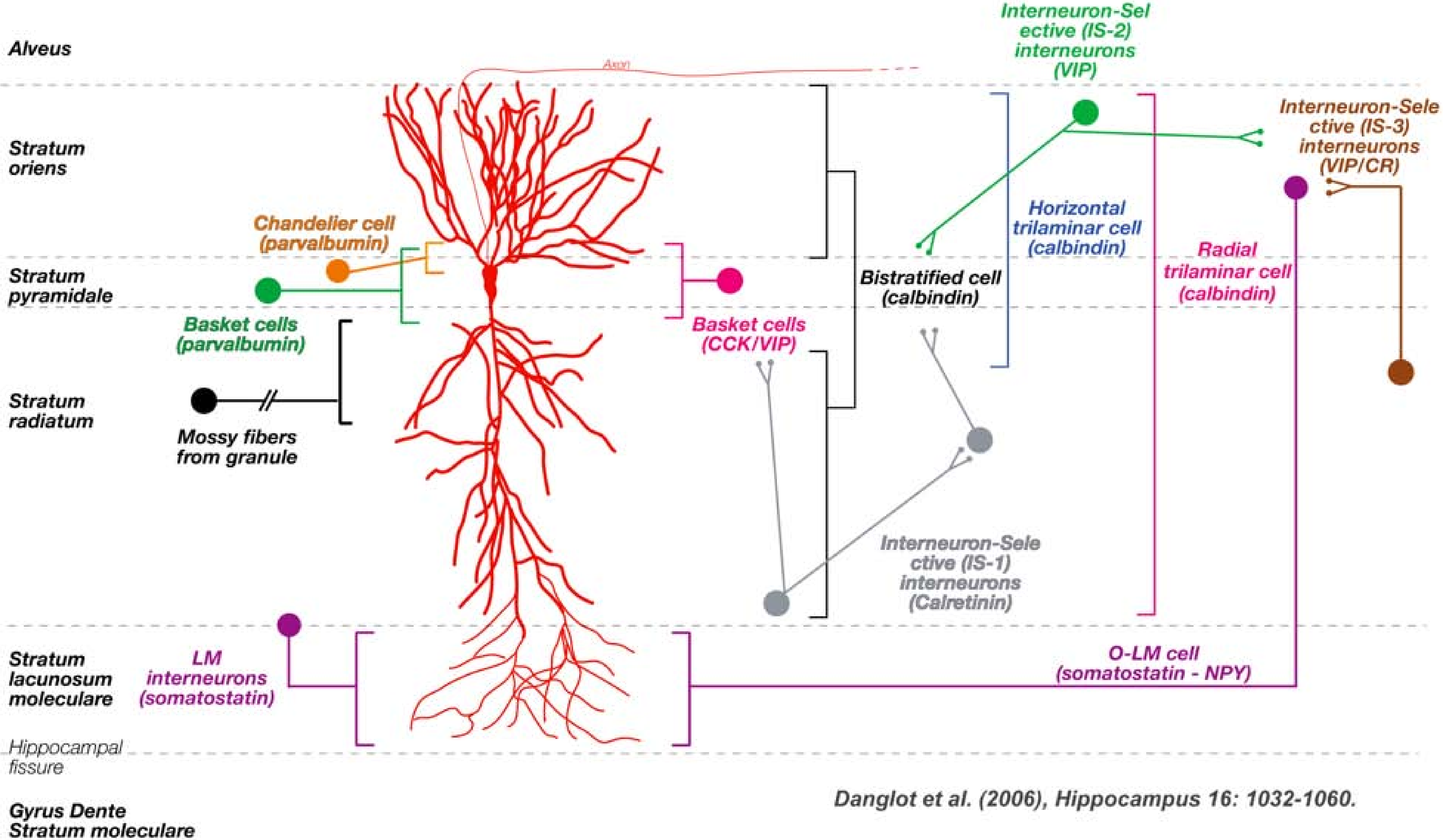


Interneurones innervant les cellules pyramidales ou grains		
Cellule en panier	SOMA des cellules excitatrices	Parvalbumine
Chandelier	Segment initial de l'axone	
Bistratifiée Trilaminaire HICAP MOPP	Dendrites proximales (sr et so)	Calbindine
O-LM LM HIPP	Dendrites distales (slm)	Somatostatine, NPY

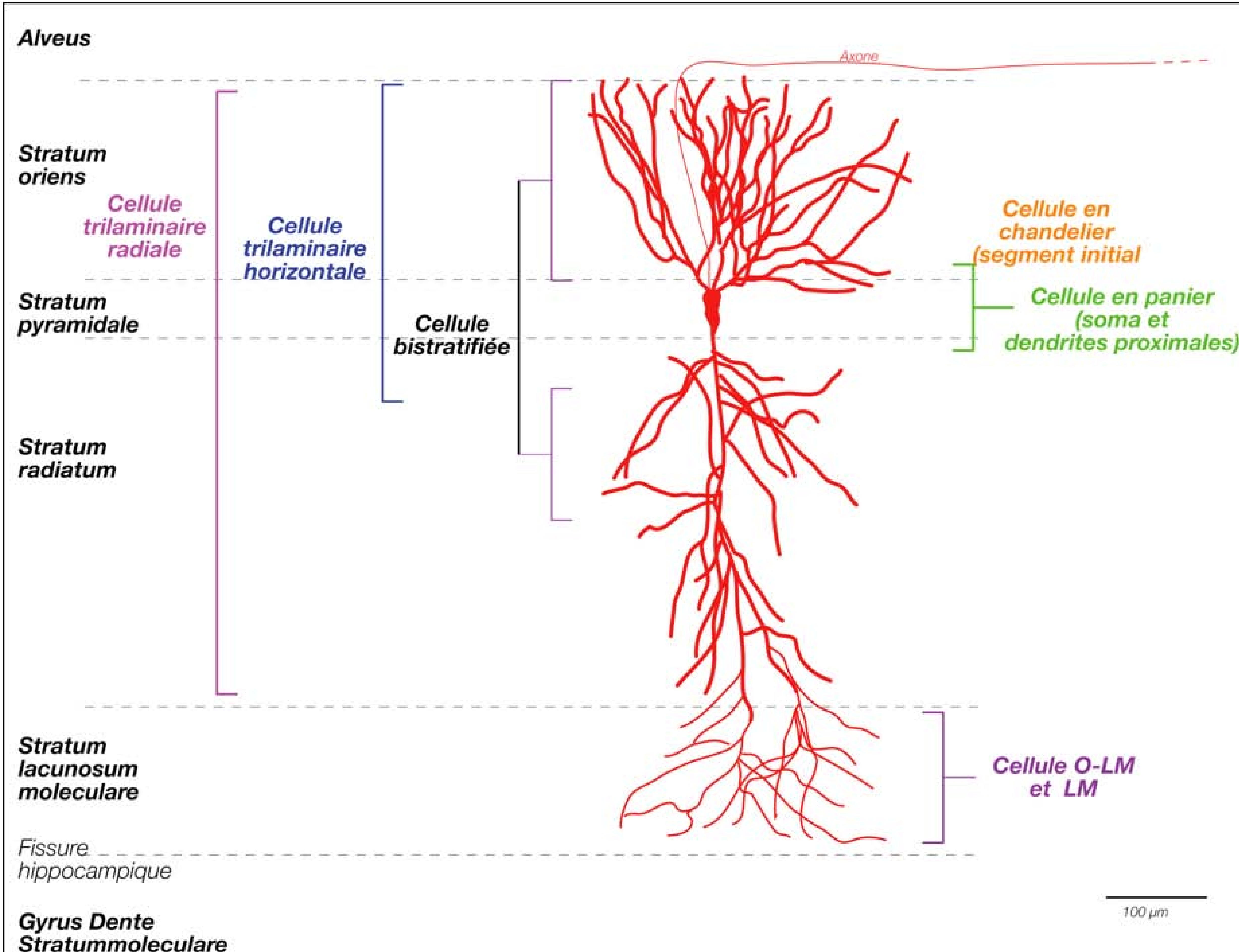
Interneurones innervant les interneurones		
IS-1, IS-2, IS-3	Dendrites	Calrétinine

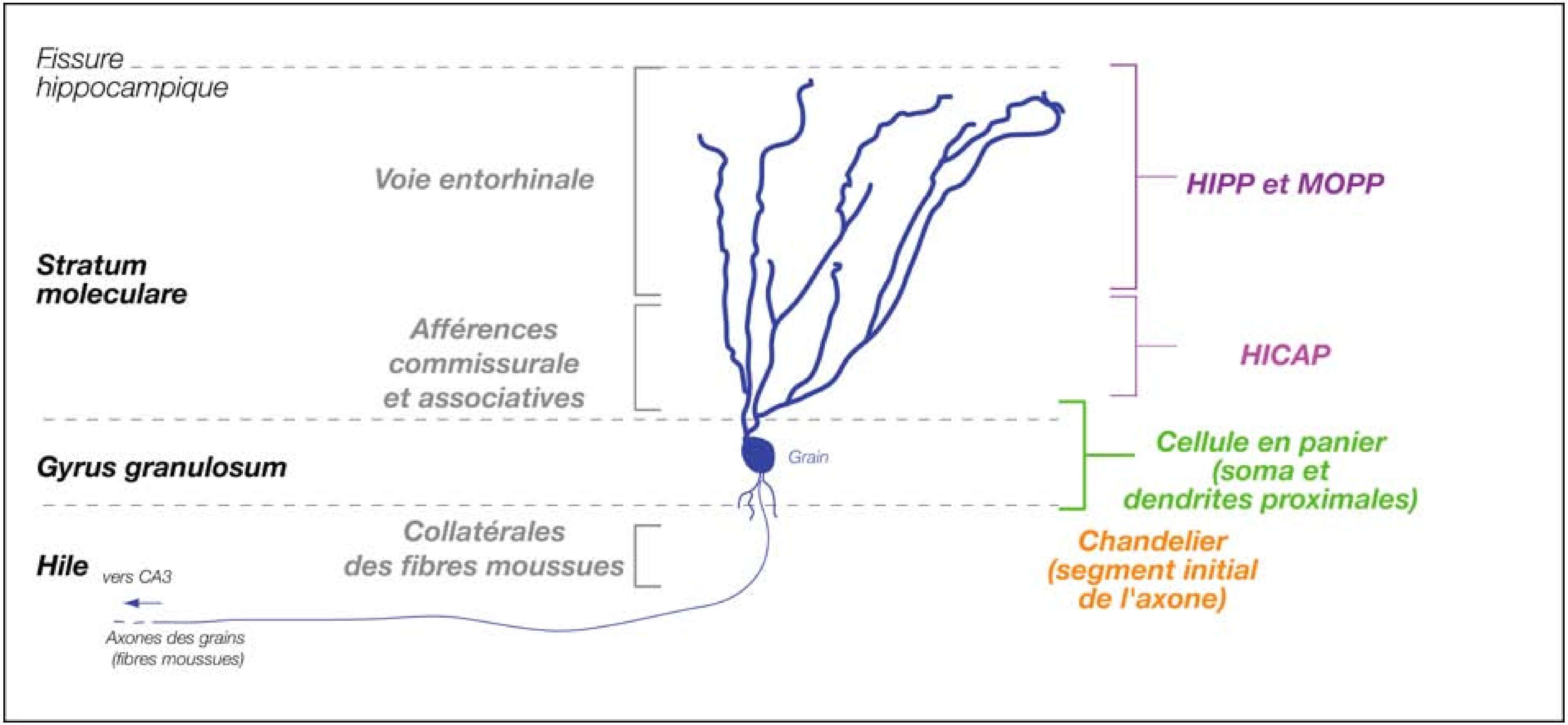
Modifié d'après Freund et al., Hippocampus,1996.

GABAergic afferences on hippocampal pyramidal cells.

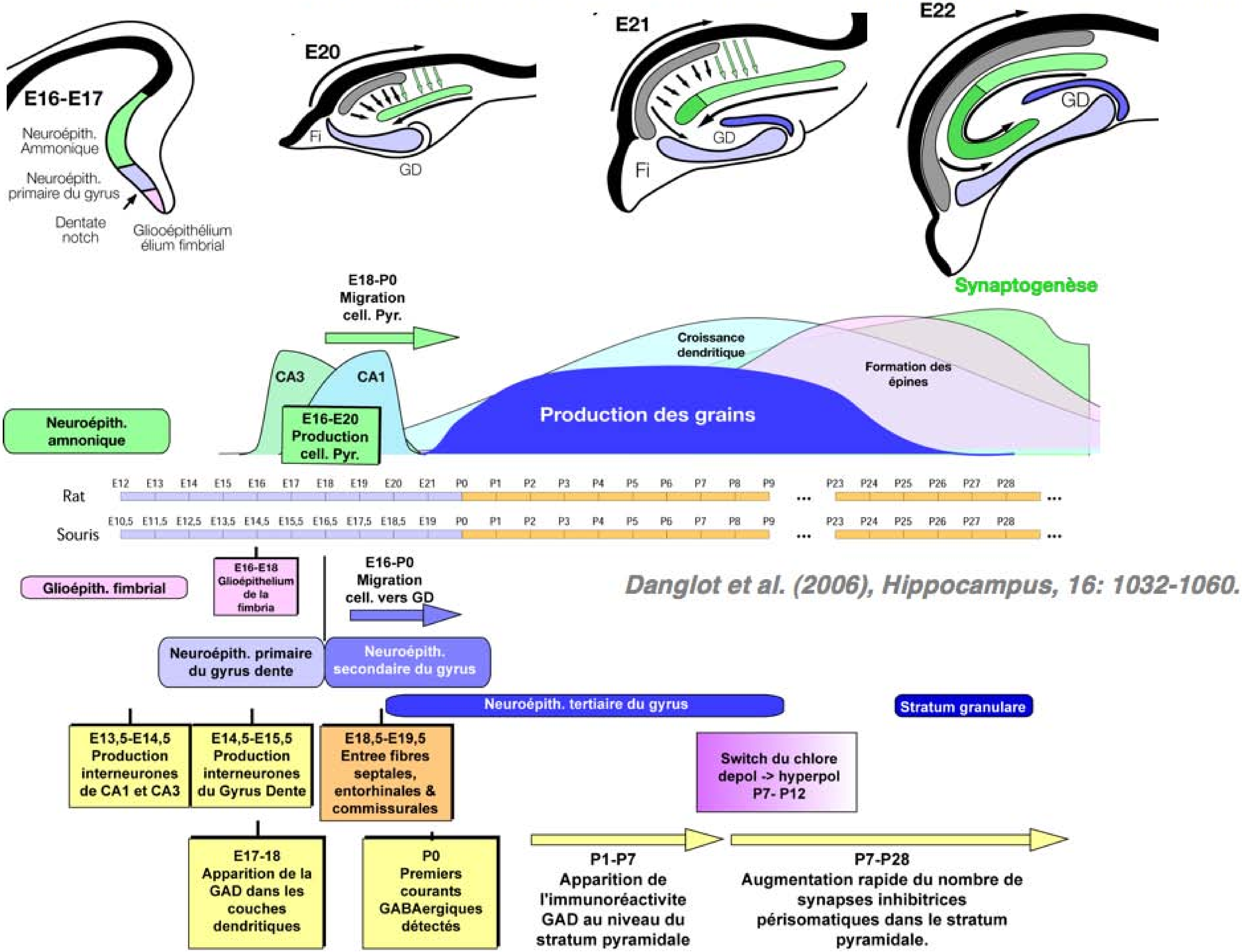


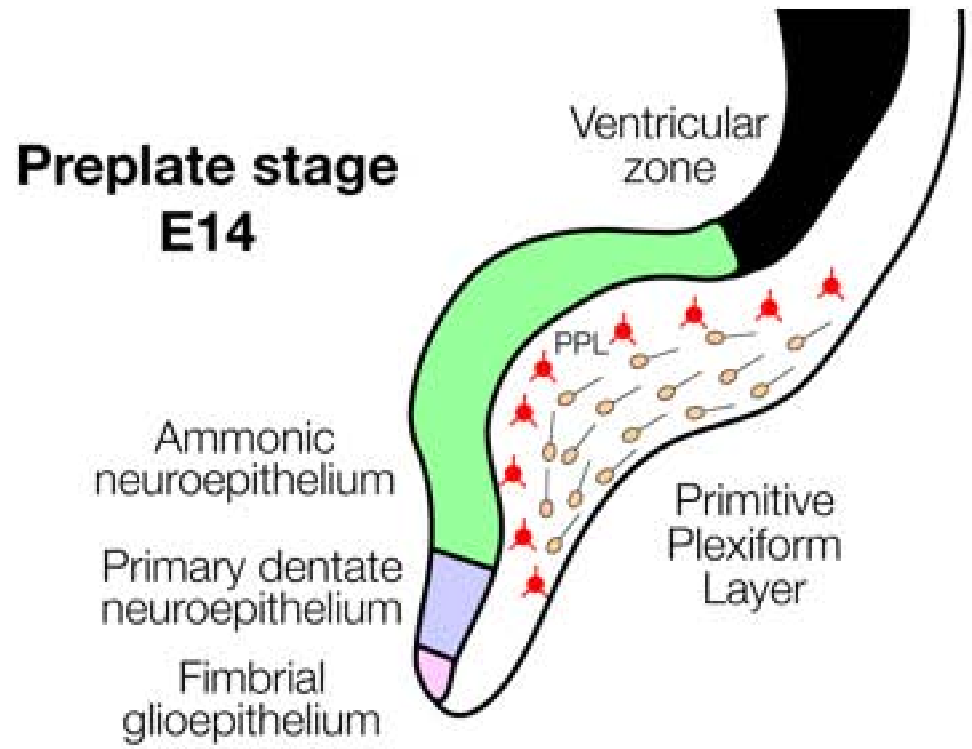
Danglot et al. (2006), Hippocampus 16: 1032-1060.

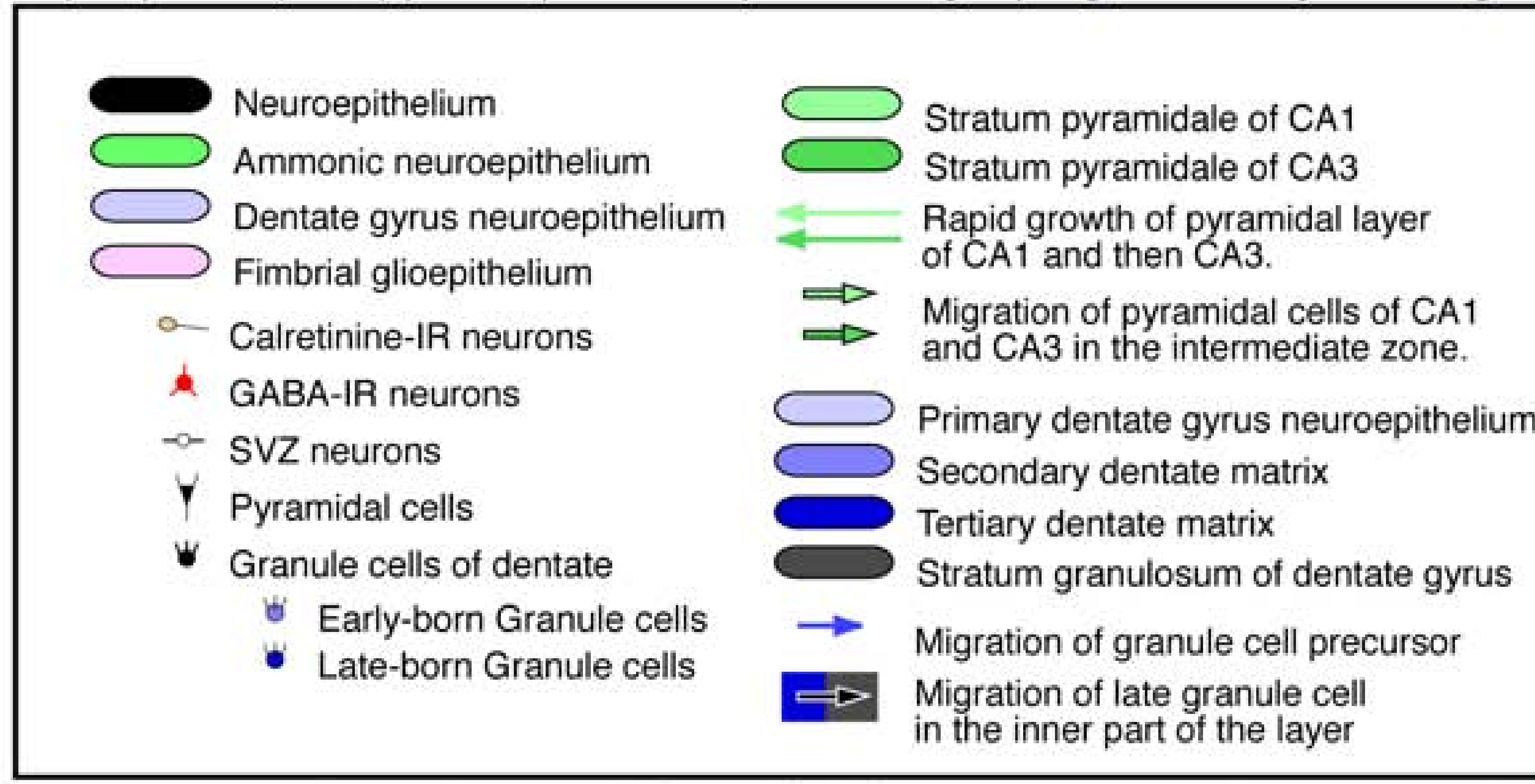

Alveus
Axone
Stratum oriens
Cellule trilaminaire radiale
Cellule trilaminaire horizontale
Cellule bistratifiée
Cellule en chandelier (segment initial
Stratum pyramidale
Cellule en panier (soma et dendrites proximales)
Stratum radiatum
Stratum lacunosum moleculare
Cellule O-LM et LM
Fissure hippocampique
Gyrus Dente Stratummoleculare
100 µm


Fissure hippocampique
Stratum moleculare
Gyrus granulosum
Hile
vers CA3
Axones des grains (fibres moussues)
Voie entorhinale
Afférences commissurale et associatives
Collatérales des fibres moussues
Grain
HIPP et MOPP
HICAP
Cellule en panier (soma et dendrites proximales)
Chandelier (segment initial de l'axone)

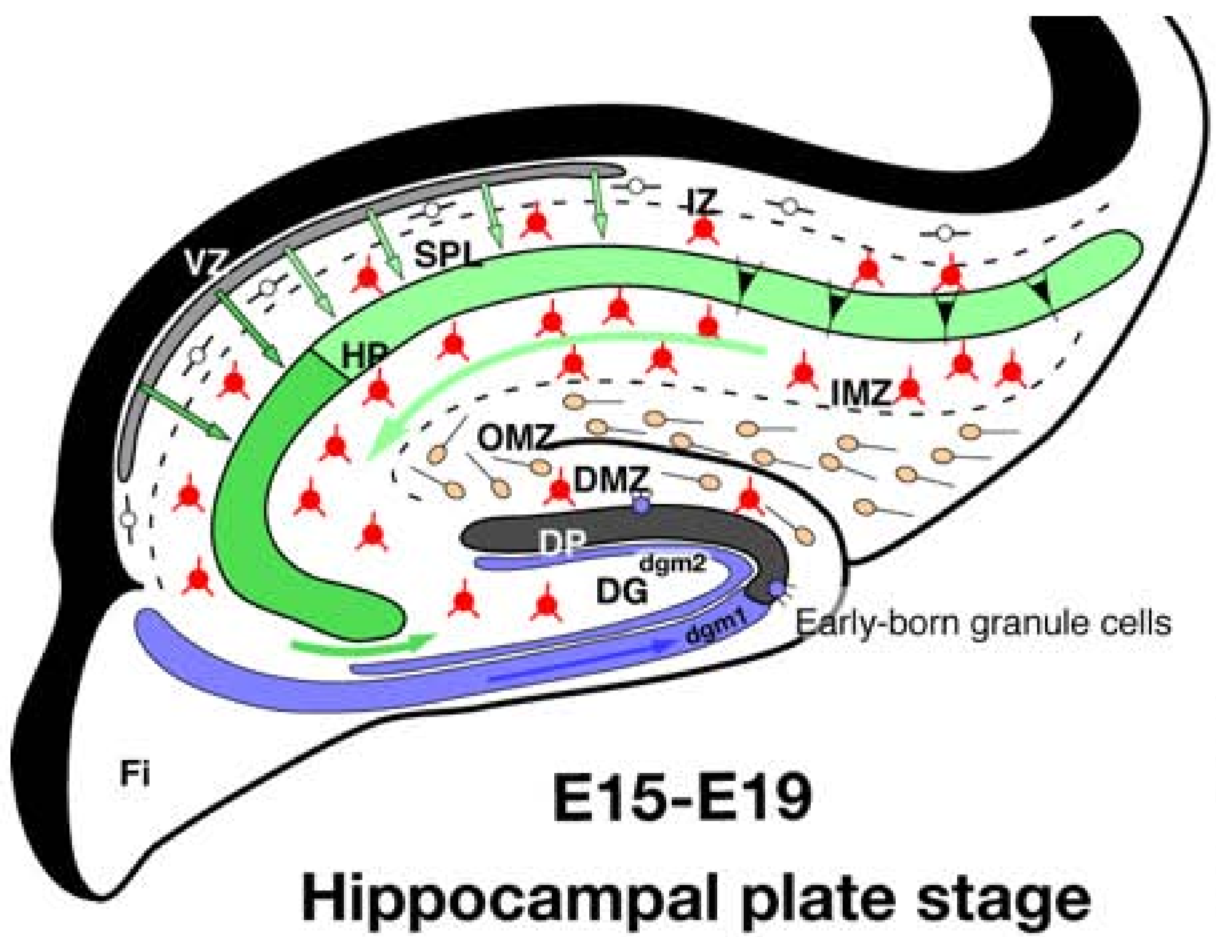
Development of the hippocampus & Cell migration

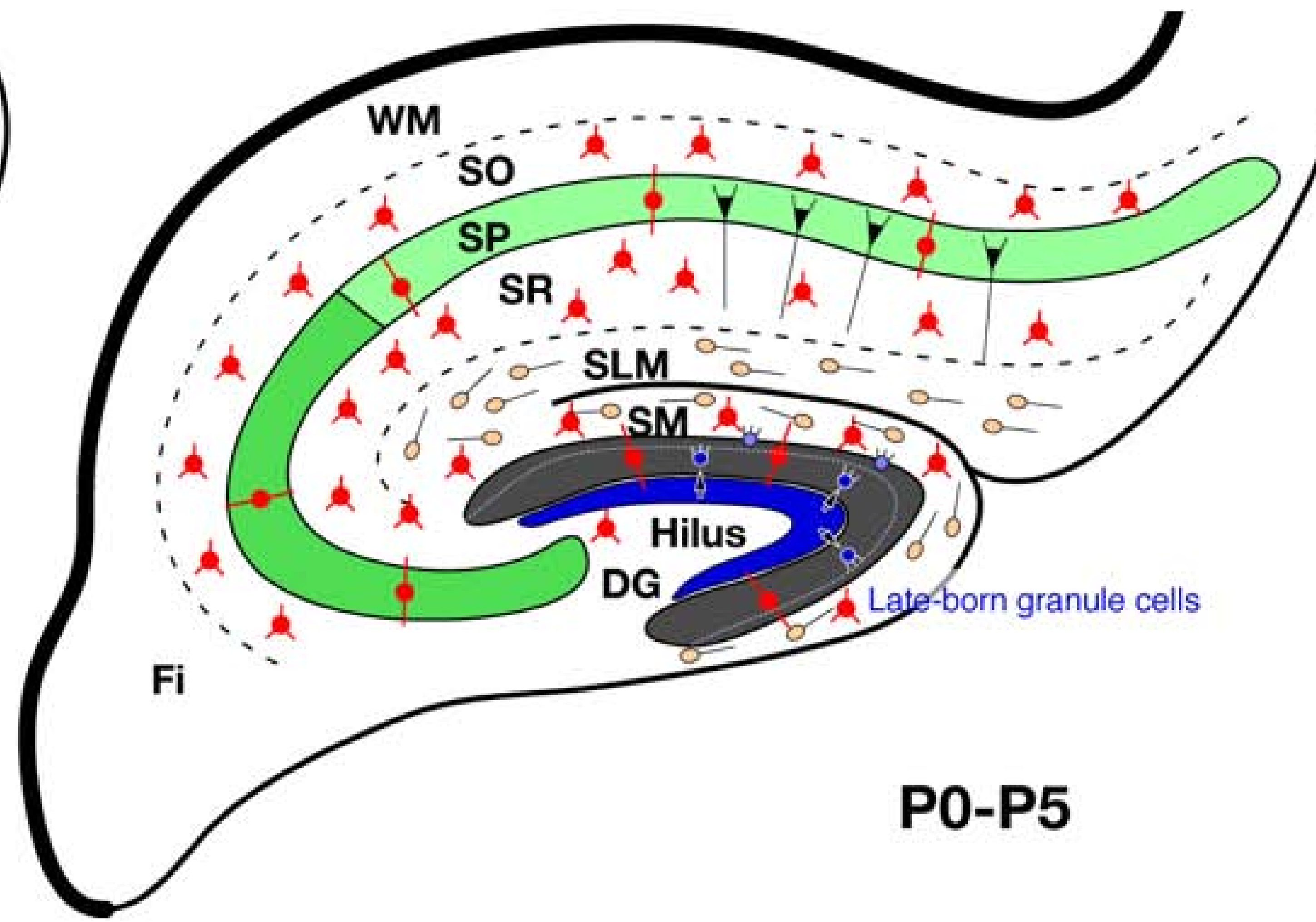

E16-E17
Neuroépith. Ammonique
Neuroépith. primaire du gyrus
Dentate notch
Gliooépithélium élium fimbrial
E20
Fi
GD
E21
Fi
GD
E22
GD
Synaptogenèse
E18-P0 Migration cell. Pyr.
Croissance dendritique
Formation des épines
CA3
CA1
Neuroépith. amnonique
E16-E20 Production cell. Pyr.
Production des grains
Rat
E12 E13 E14 E15 E16 E17 E18 E19 E20 E21 P0 P1 P2 P3 P4 P5 P6 P7 P8 P9 ... P23 P24 P25 P26 P27 P28 ...
Souris
E10,5 E11,5 E12,5 E13,5 E14,5 E15,5 E16,5 E17,5 E18,5 E19 P0 P1 P2 P3 P4 P5 P6 P7 P8 P9 ... P23 P24 P25 P26 P27 P28 ...
Glioépith. fimbrial
E16-E18 Glioépithelium de la fimbria
E16-P0 Migration cell. vers GD
Danglot et al. (2006), Hippocampus, 16: 1032-1060.
Neuroépith. primaire du gyrus dente
Neuroépith. secondaire du gyrus
Neuroépith. tertiaire du gyrus
Stratum granulare
E13,5-E14,5 Production interneurones de CA1 et CA3
E14,5-E15,5 Production interneurones du Gyrus Dente
E18,5-E19,5 Entree fibres septales, entorhinales & commissurales
Switch du chlore depol -> hyperpol P7- P12
E17-18 Apparition de la GAD dans les couches dendritiques
P0 Premiers courants GABAergiques détectés
P1-P7 Apparition de l'immunoréactivite GAD au niveau du stratum pyramidale
P7-P28 Augmentation rapide du nombre de synapses inhibitrices périsomatiques dans le stratum pyramidale.





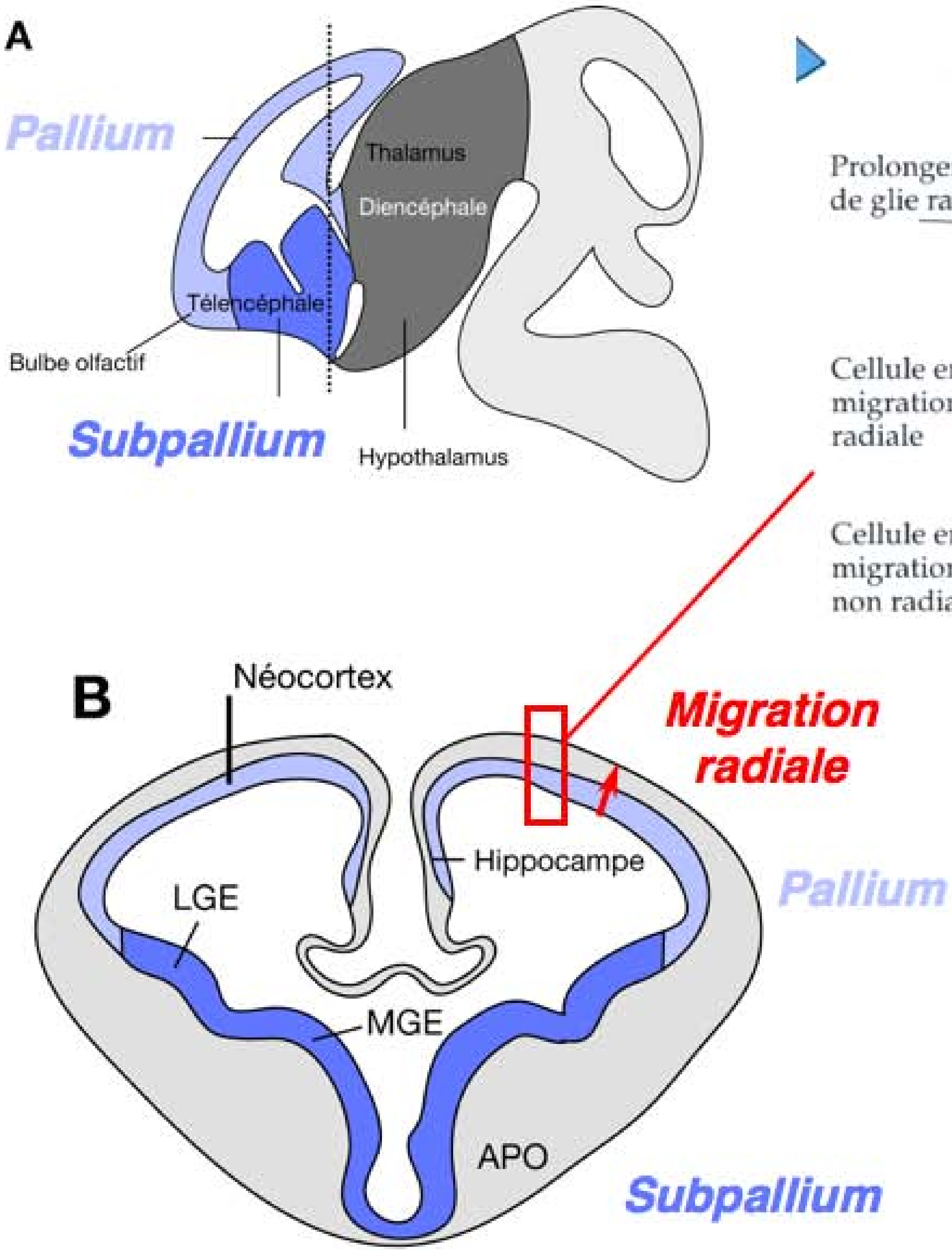
Danglot et al. (2006), Hippocampus, 16: 1032-1060.

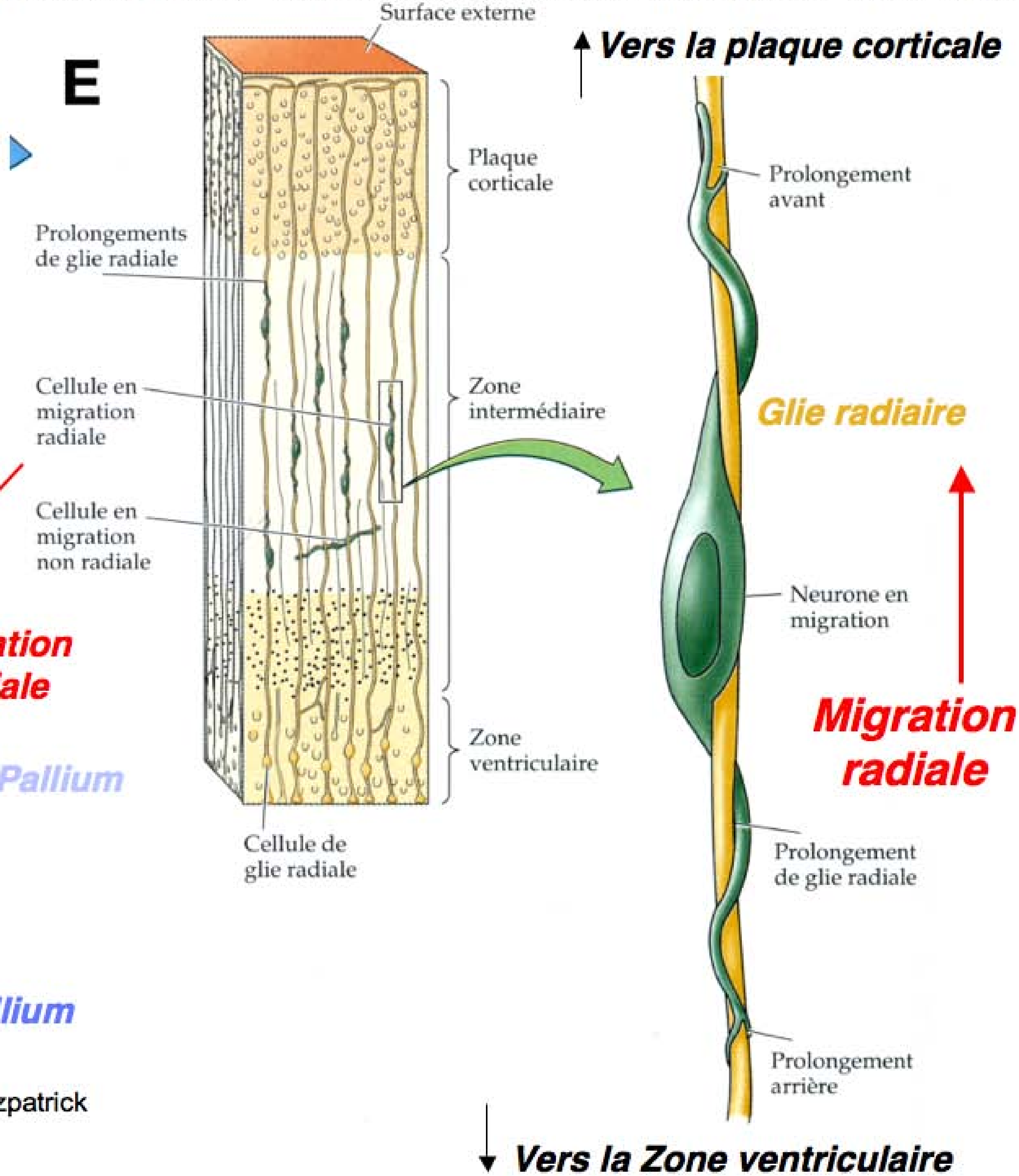




Modes of migration of excitatory cells

Télencéphale





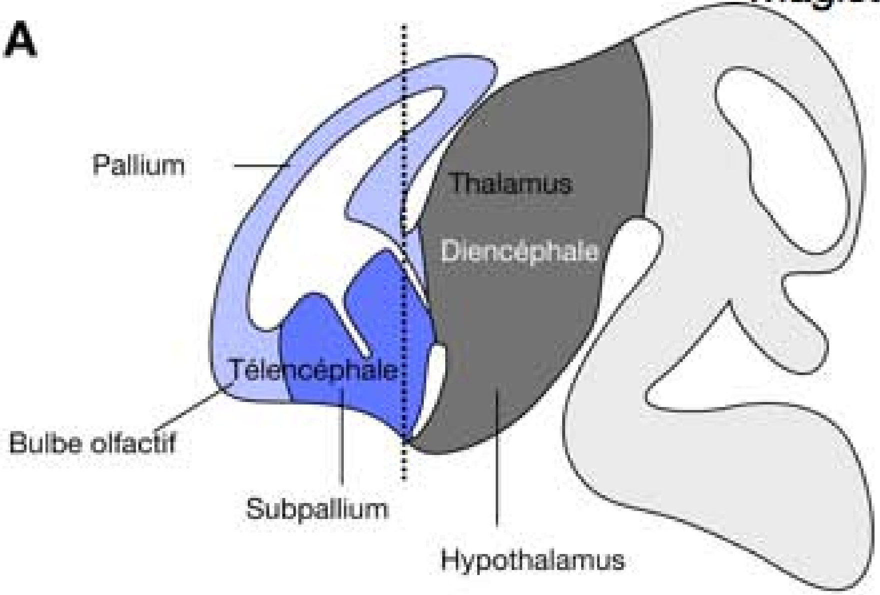
Adapted from « Neurosciences »:
De Dale Purves, George J. Augustine, David Fitzpatrick
Traduit par Jean-Marie Coquery
De Boeck Université 3ème édition, 2005

Nature Reviews Neuroscience 3, 423-432 (June 2002)

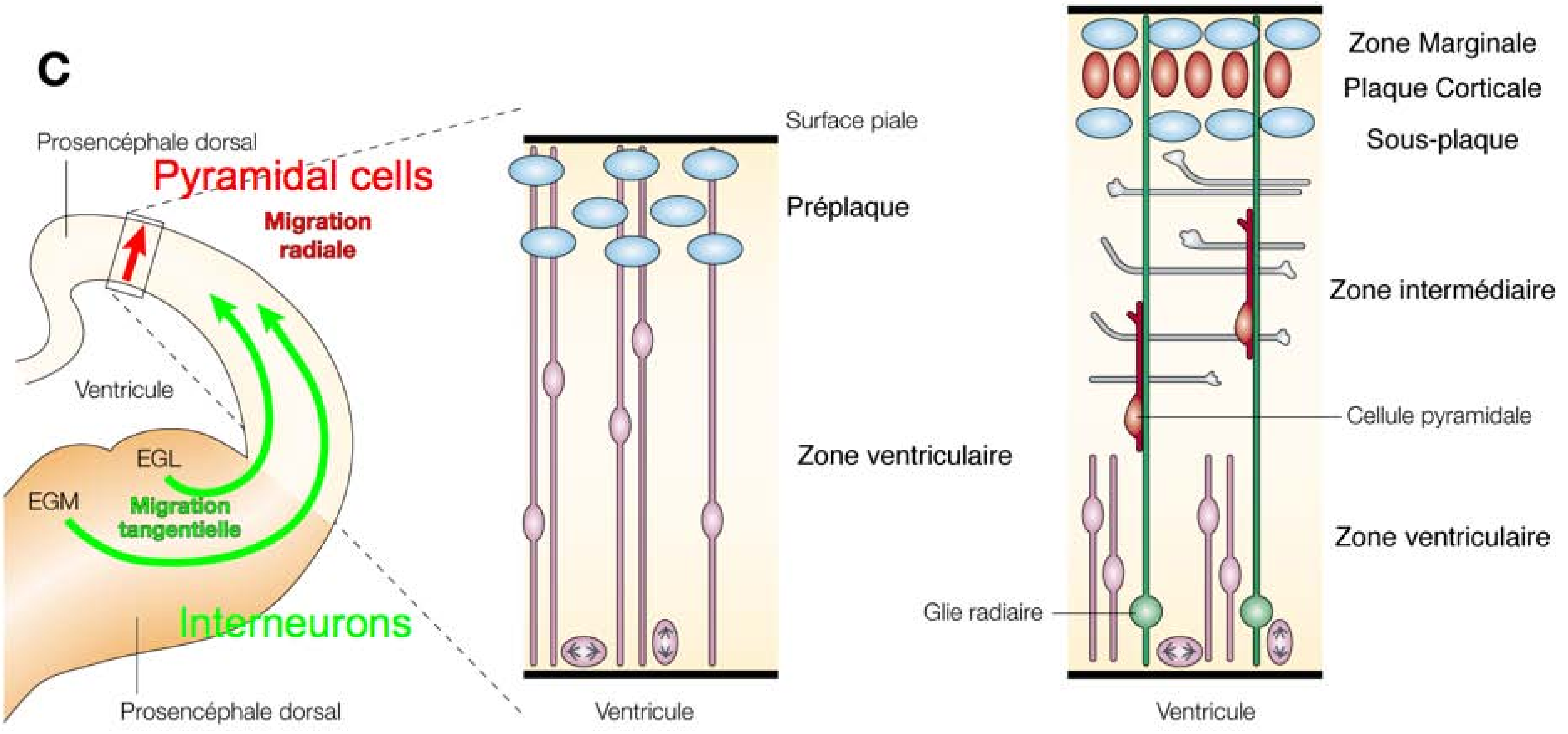
Modes of neuronal migration in the developing cerebral cortex

Bagirathy Nadarajah & John G. Parnavelas

A

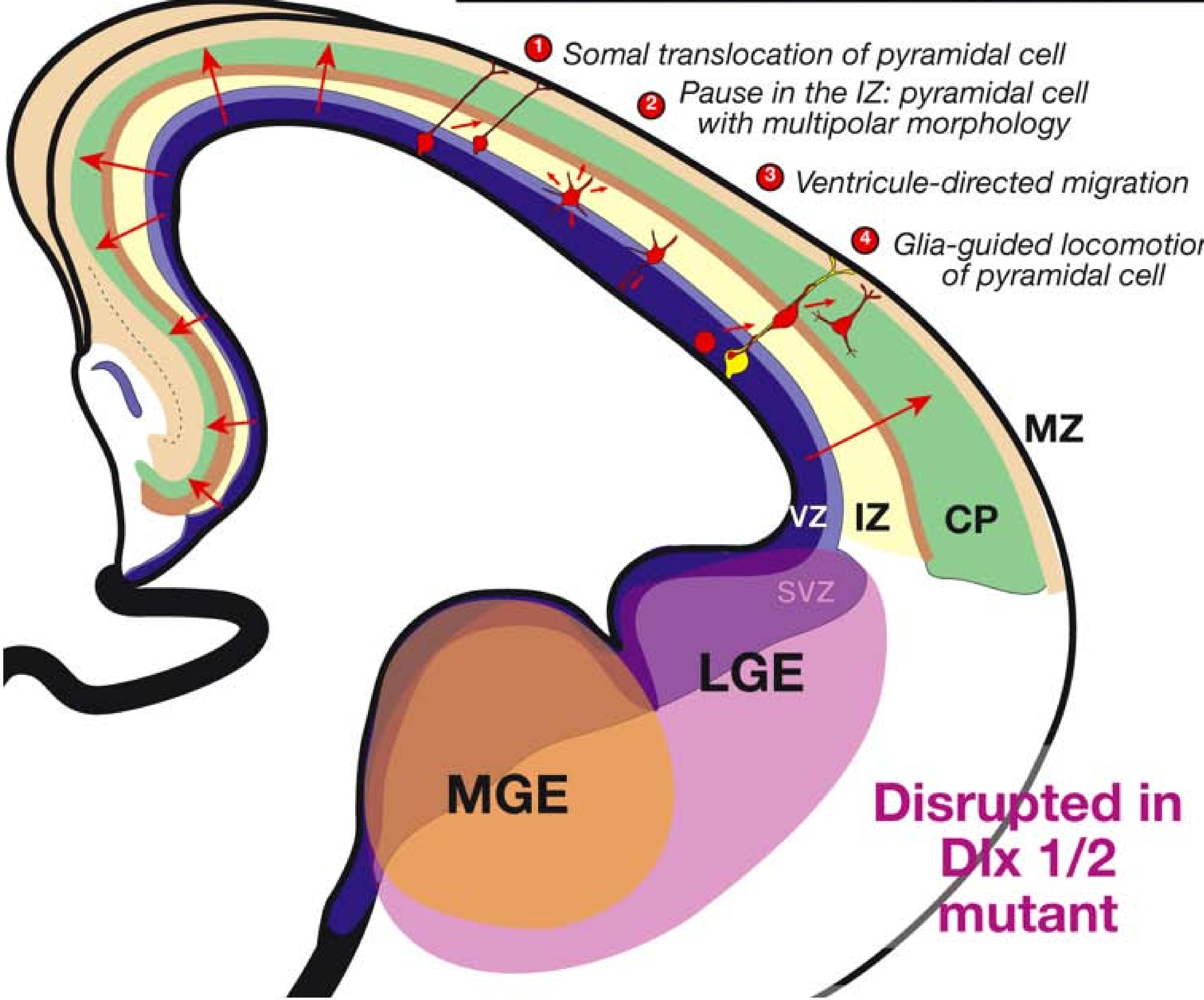


C



Prosencéphale en dévelopement **Stade de la préplaque** **Stade de la plaque corticale**

Radial migration of pyramidal cells



Danglot et al. (2006), hippocampus 16: 1032-1060.

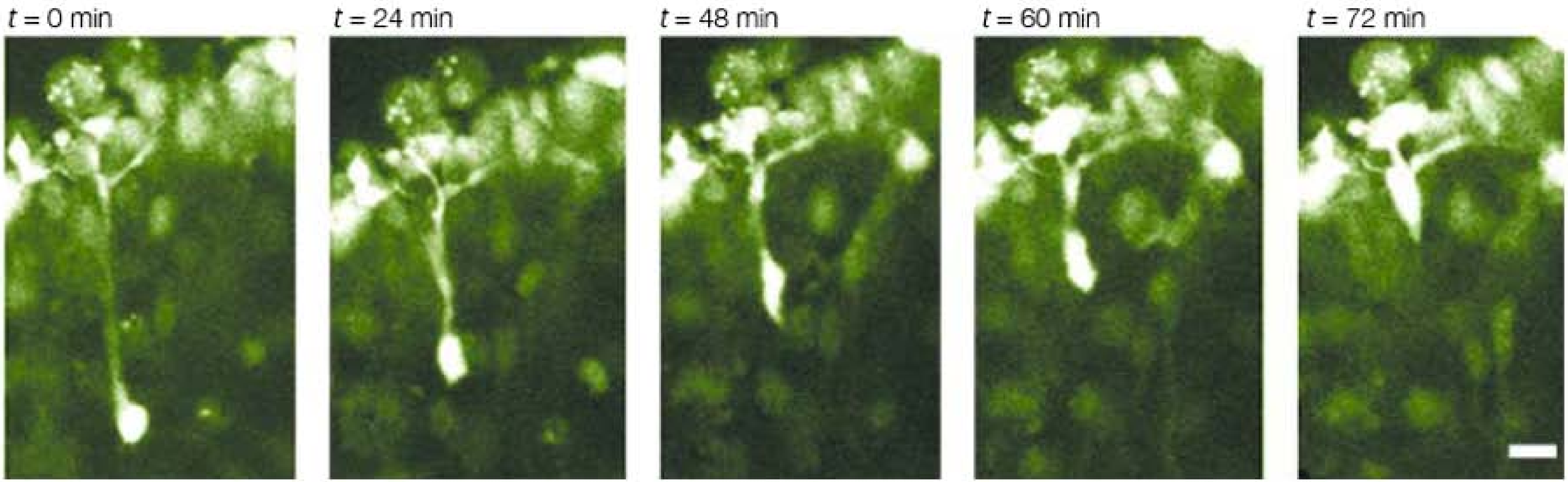


Figure 3 | **Somal translocation.** Time-lapse images of a cell showing somal translocation in a mouse cortical slice that was labelled with Oregon Green BAPTA-1 488 AM. Images were acquired every minute and each frame shows a single optical section. Scale bar, 10 µm. See Supplementary Movie from REF. 31 © 2001 Macmillan Magazines Ltd.

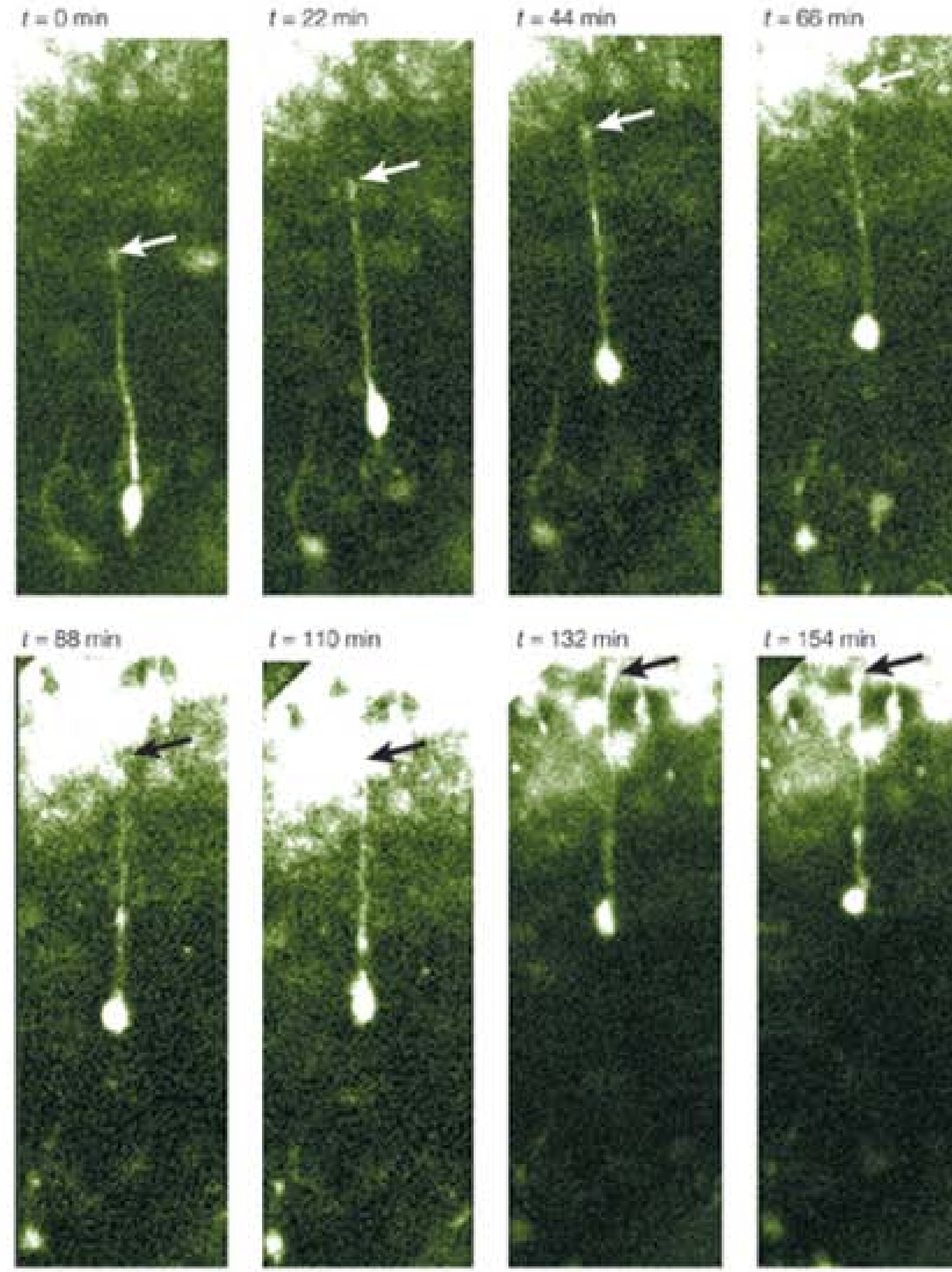
Nadarajah & Parnavelas
Nat Rev Neur (2002)vol.3:423.

Somal translocation

Nadarajah, Nature Neurosci. 4, 143–150 (2001).

Glia-guided locomotion

Nadarajah, Nature Neurosci. 4, 143–150 (2001).

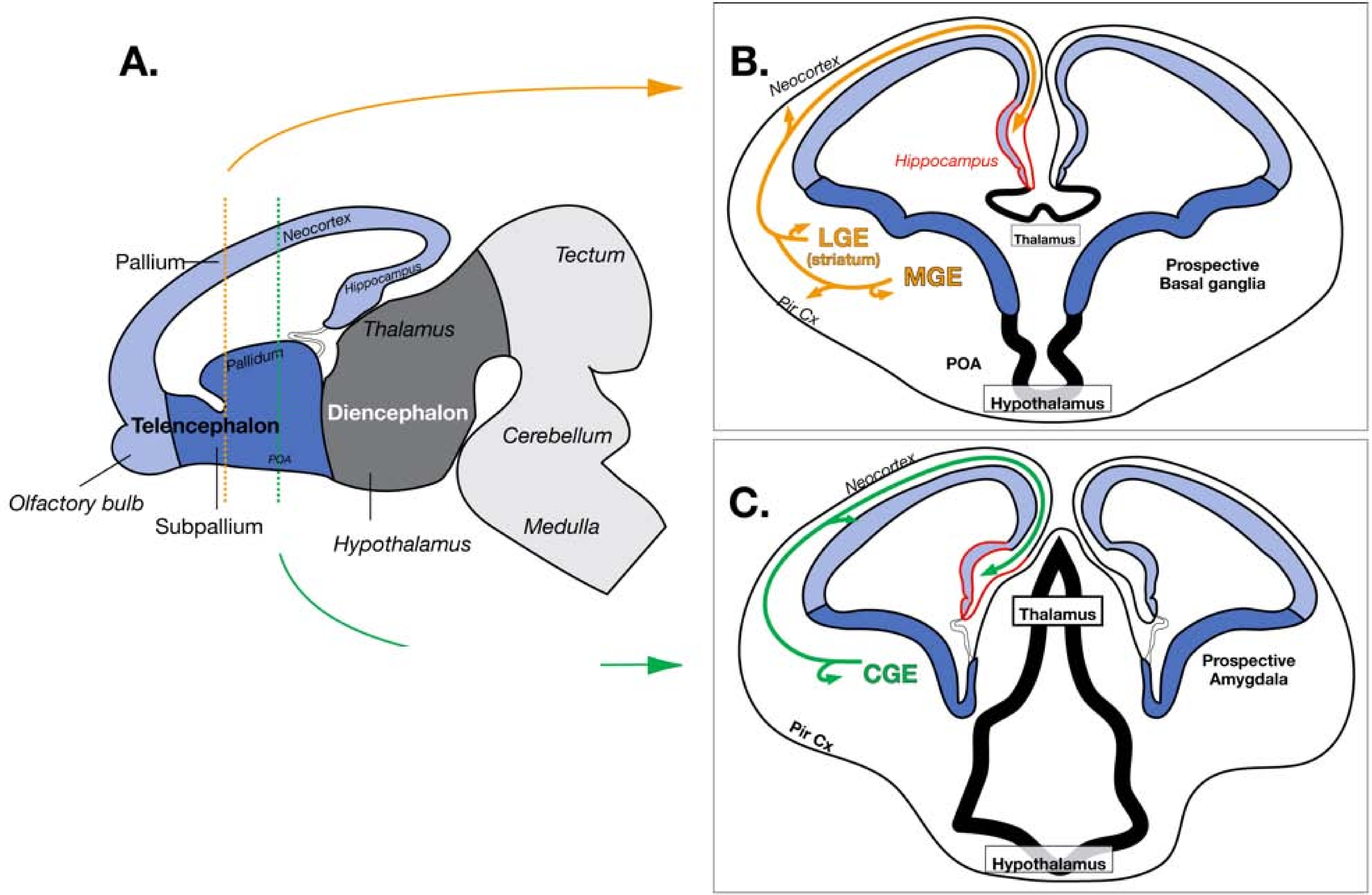


Nadarajah & Parnavelas
Nat Rev Neur (2002)vol.3:423.

Nature Reviews | Neuroscience

Modes of migration of inhibitory cells

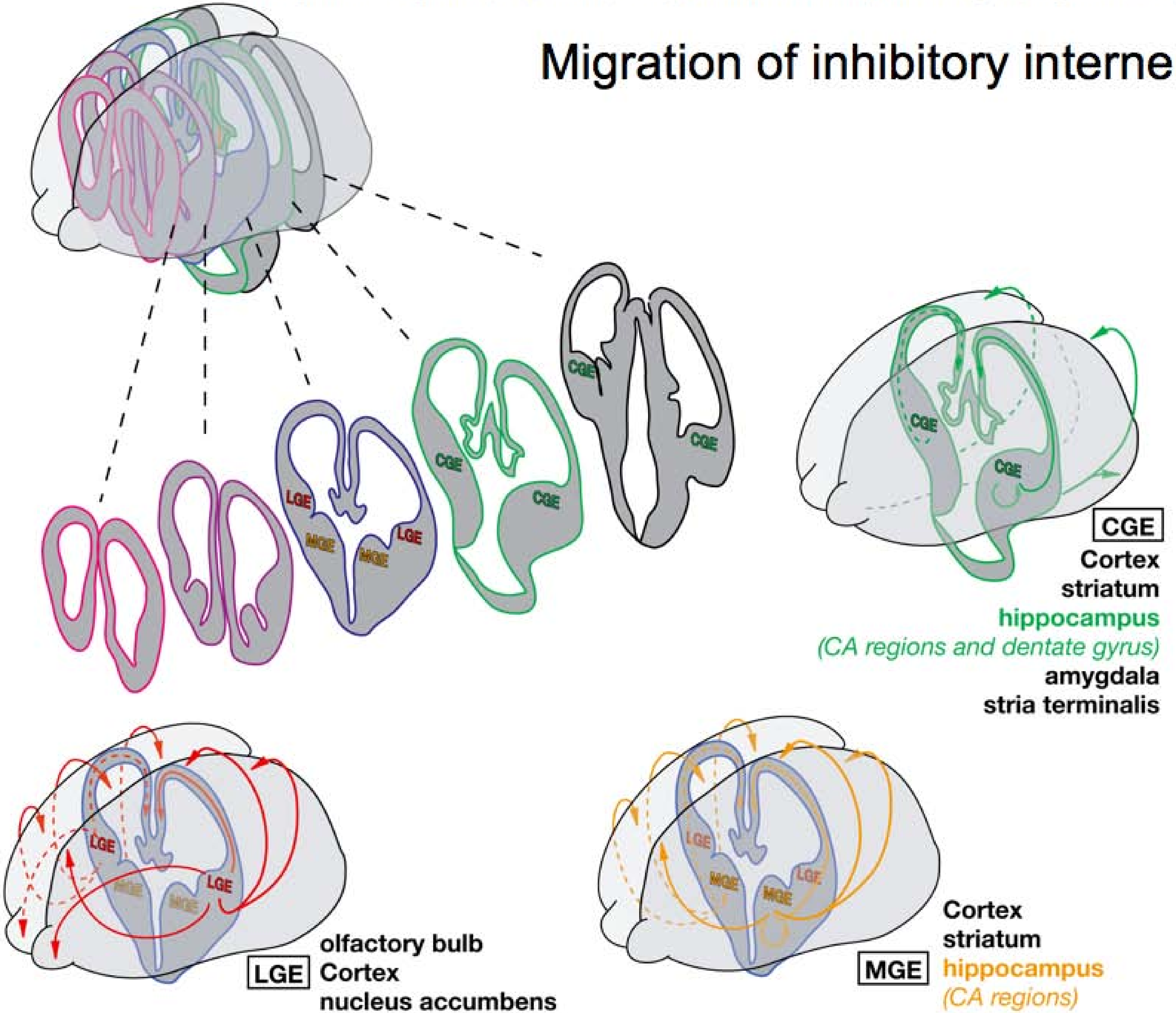
Migration of inhibitory interneurons



Danglot et al. (2006), Hippocampus 16: 1032-1060.

D.

Migration of inhibitory interneurons



Danglot et al. (2006), Hippocampus 16: 1032-1060.

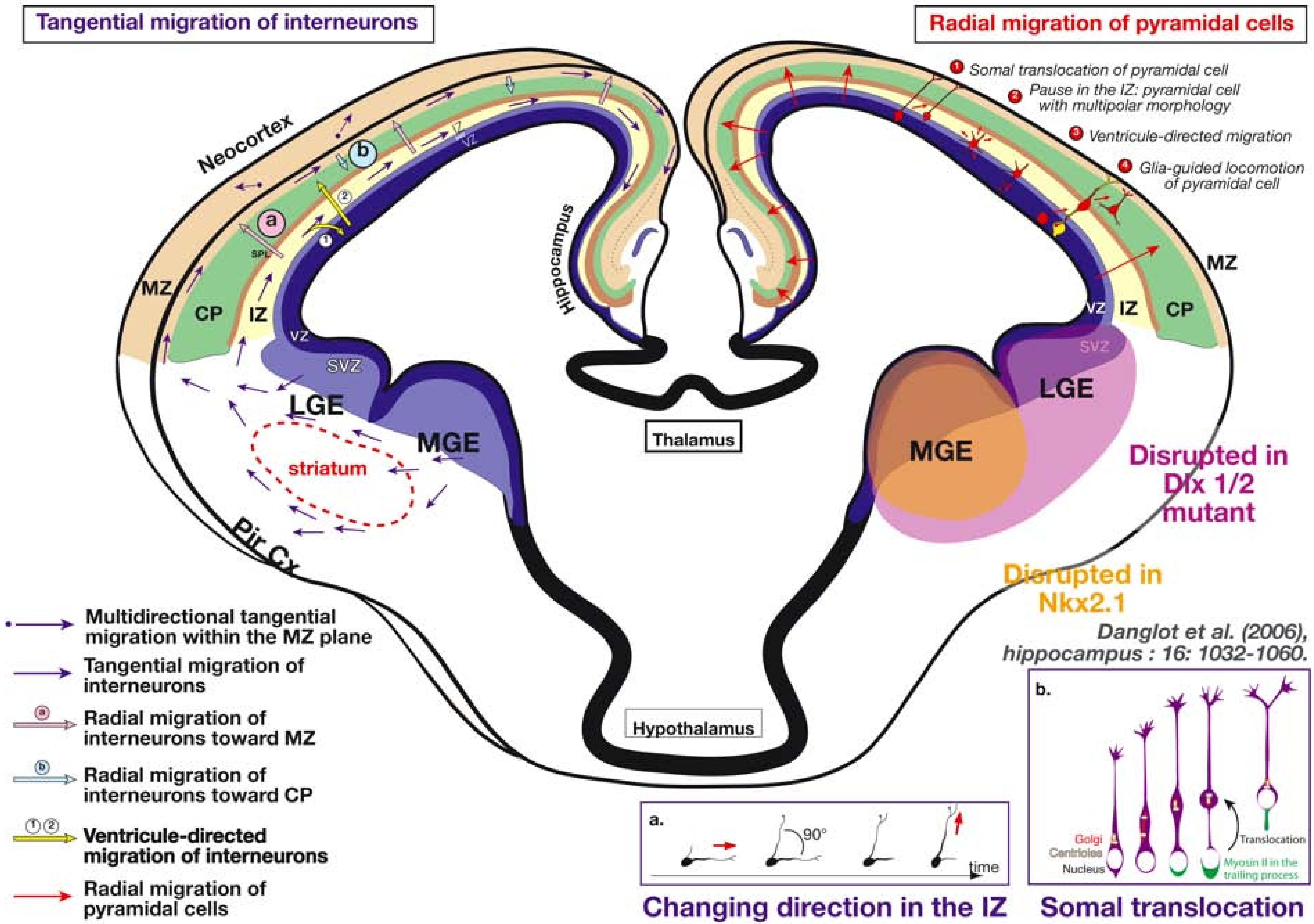
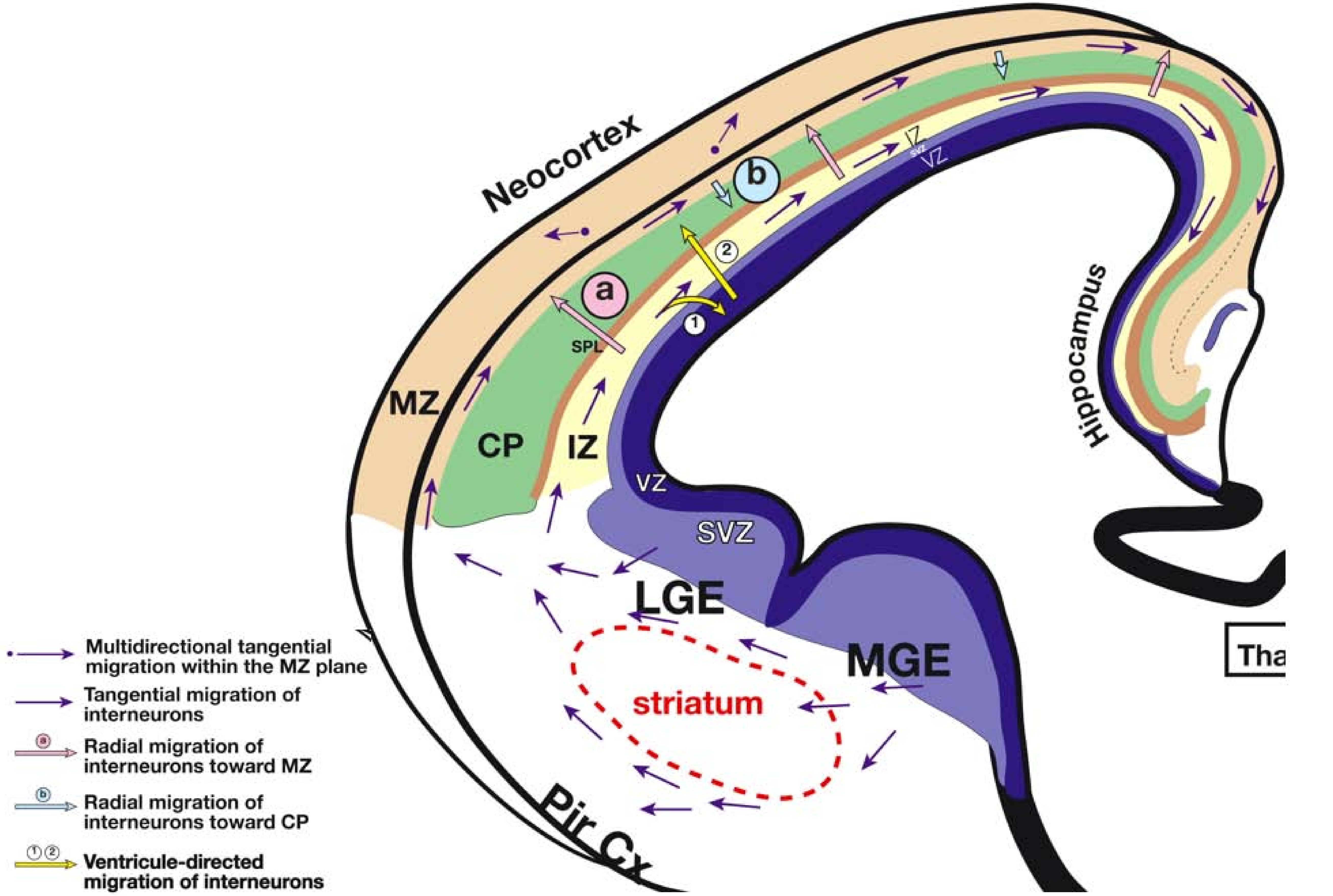


Figure 5 : Modes of migration of interneurons from the subpallial telencephalon toward the cortical and hippocampal anlagen.

Tangential migration of interneurons

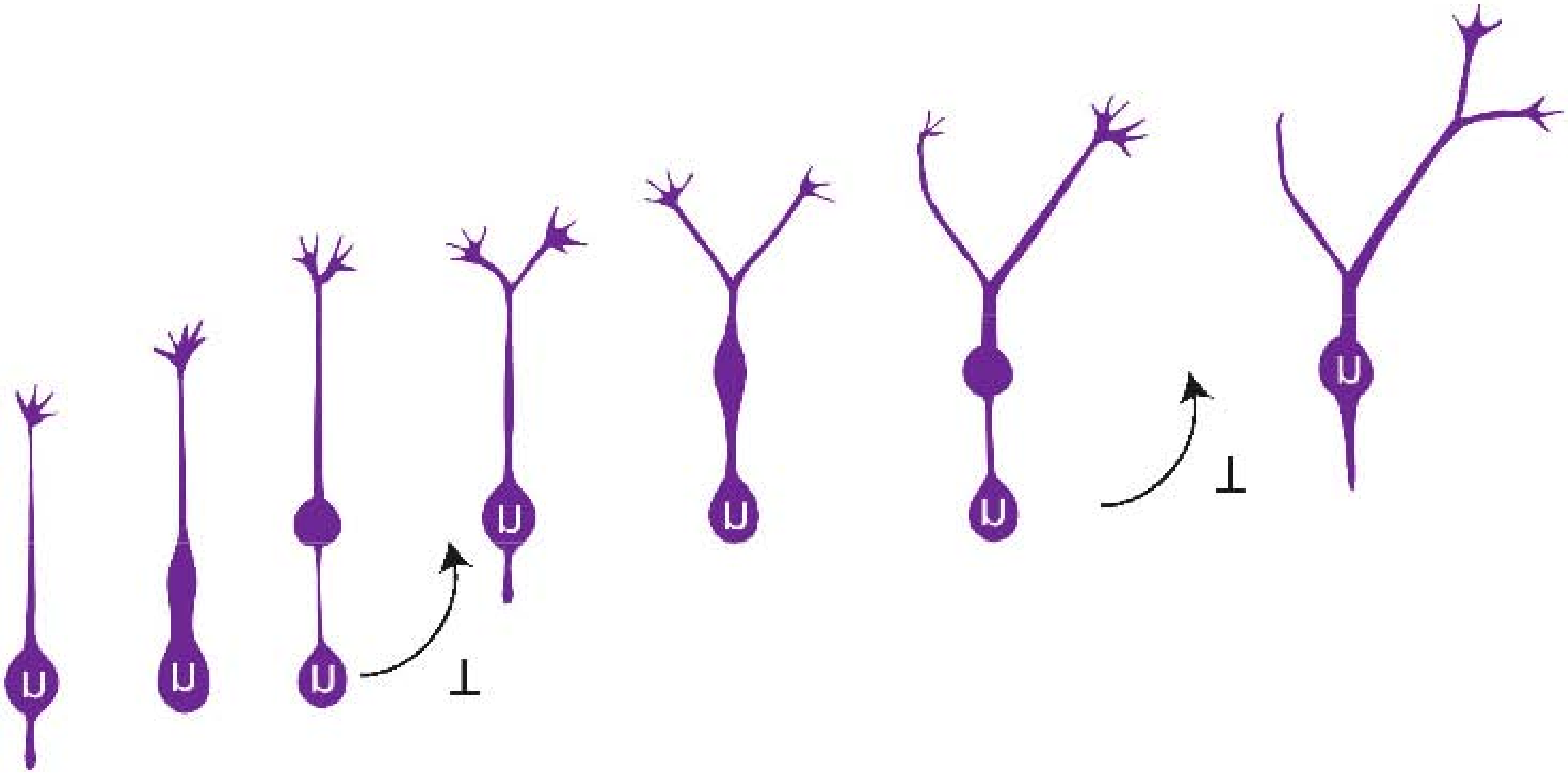


European Journal of Neuroscience, Vol. 23, pp. 894–900, 2006

doi:10.1111/j.1460-9568.2006.04630.x

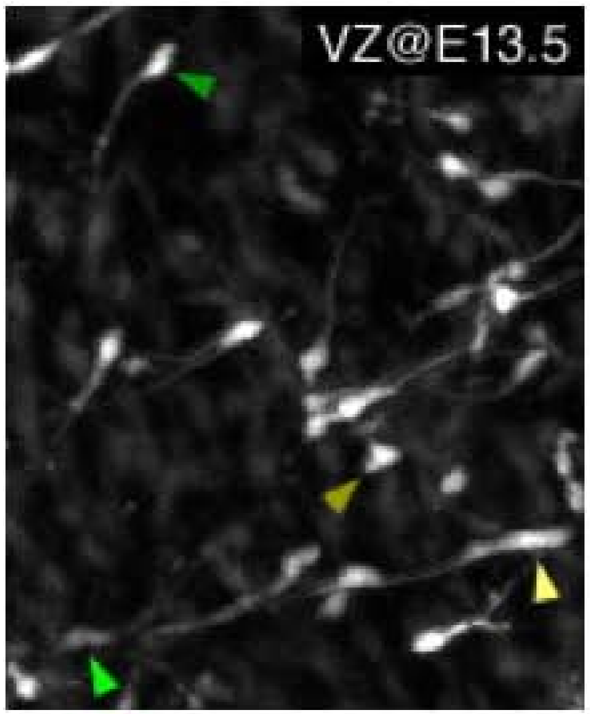
REVIEW ARTICLE
Cell and molecular mechanisms involved in the migration of cortical interneurons

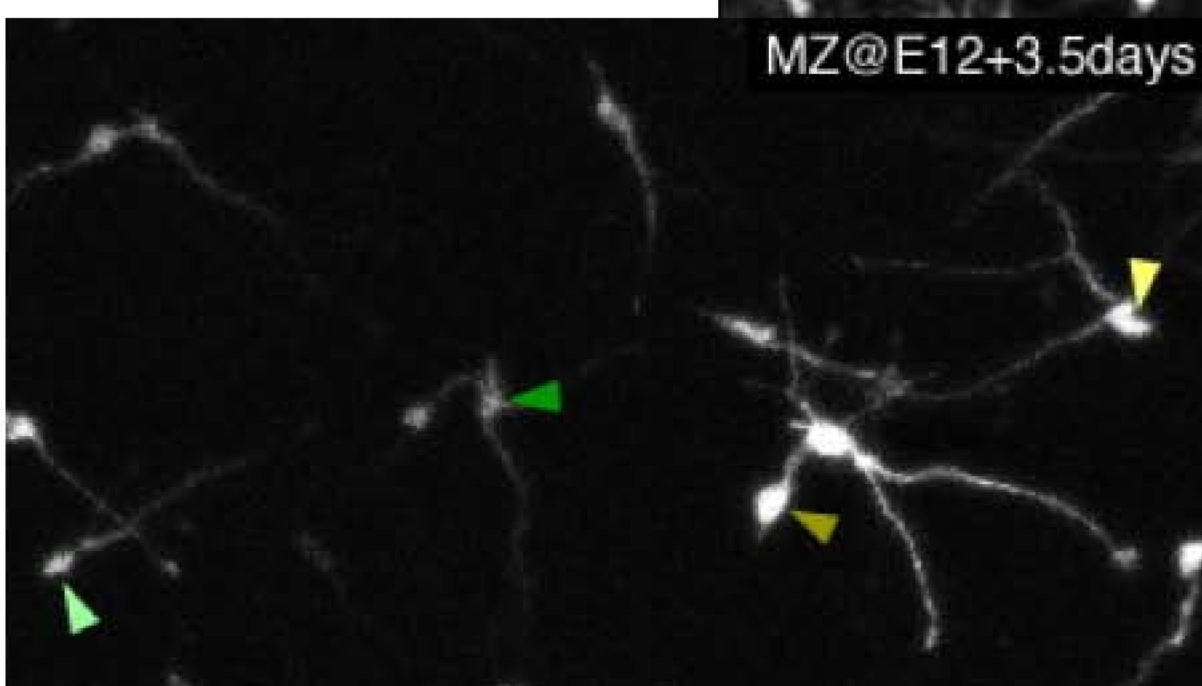
Christine Métin,[1,2] Jean-Pierre Baudoin,[1,2] Sonja Rakić[3] and John G. Parnavelas[3]

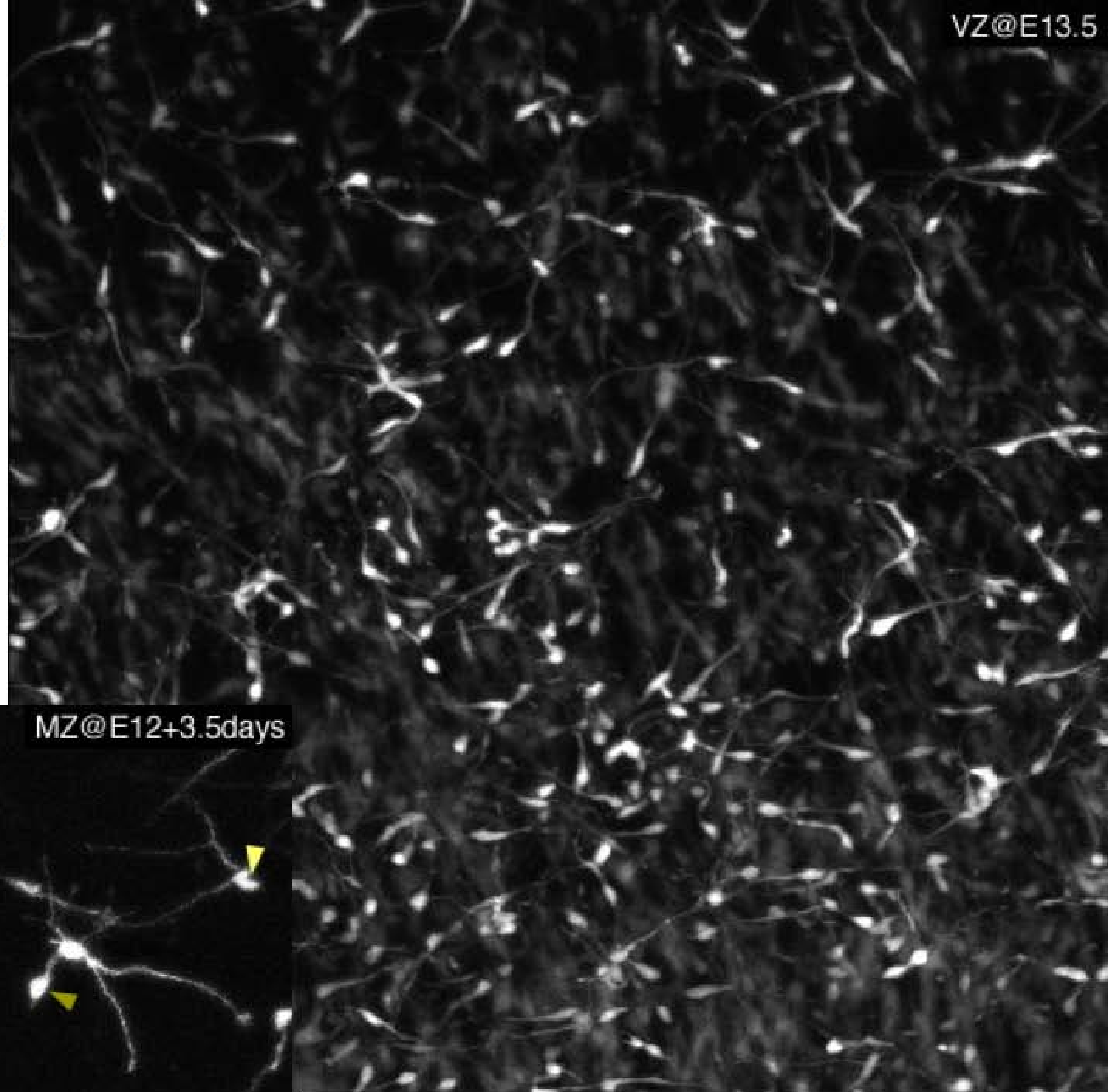


Multidirectional and multizonal tangential migration of GABAergic interneurons in the developing cerebral cortex

Development 133, 2167-2176 (2006)

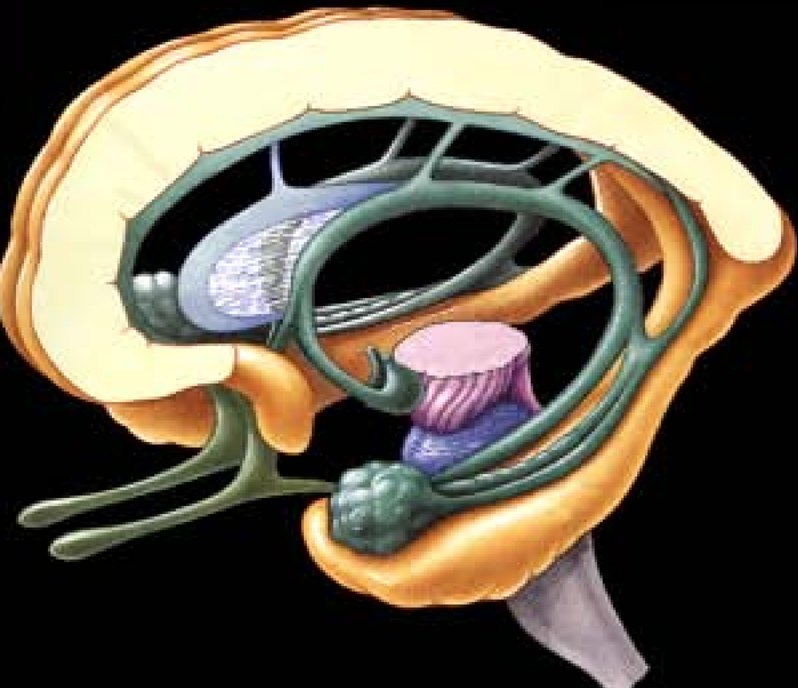


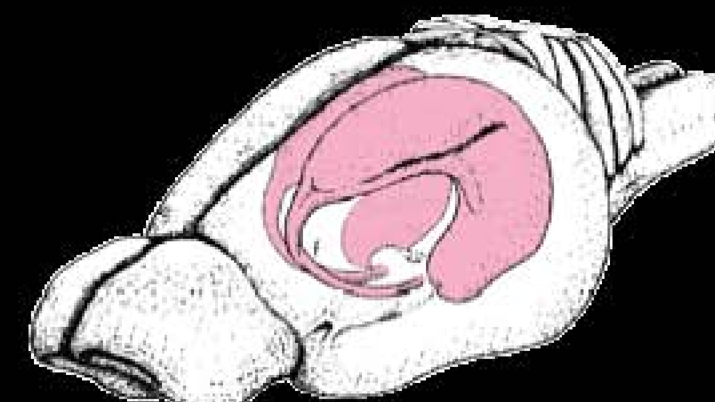


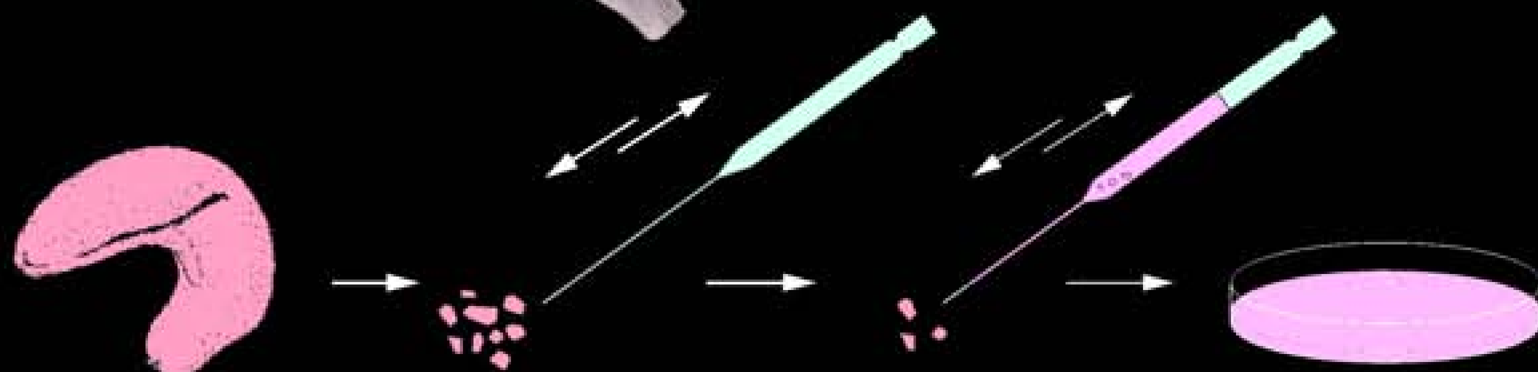


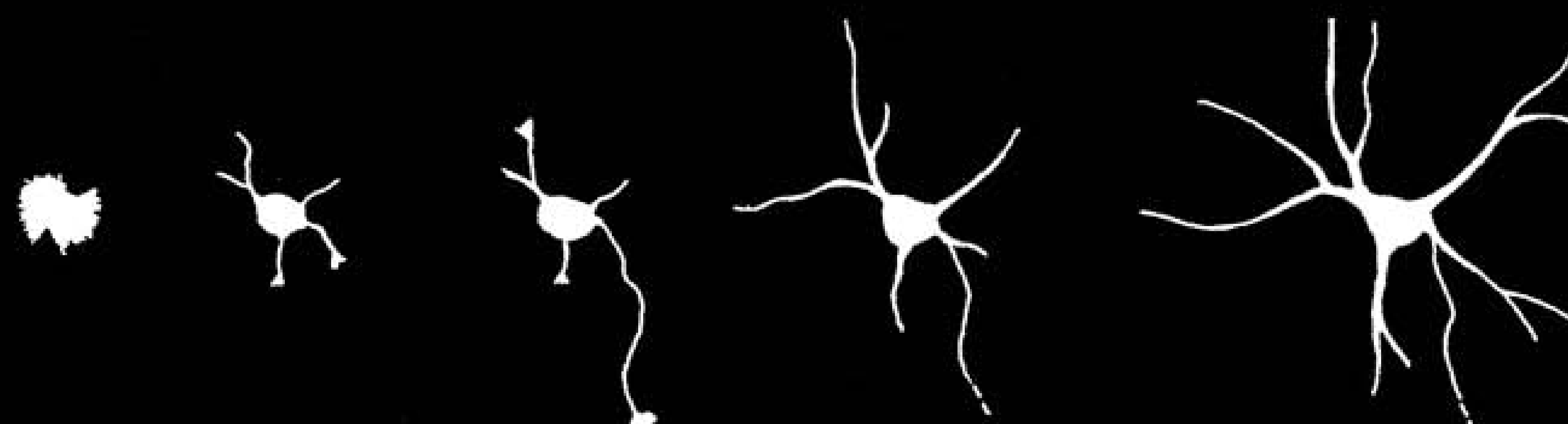
Synaptogenesis

Hippocampal neurons in culture

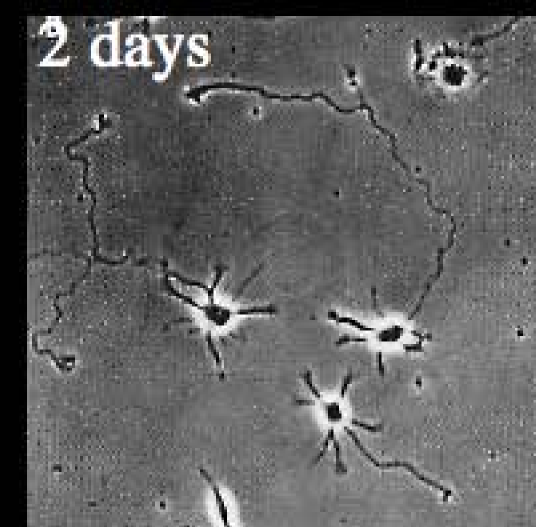


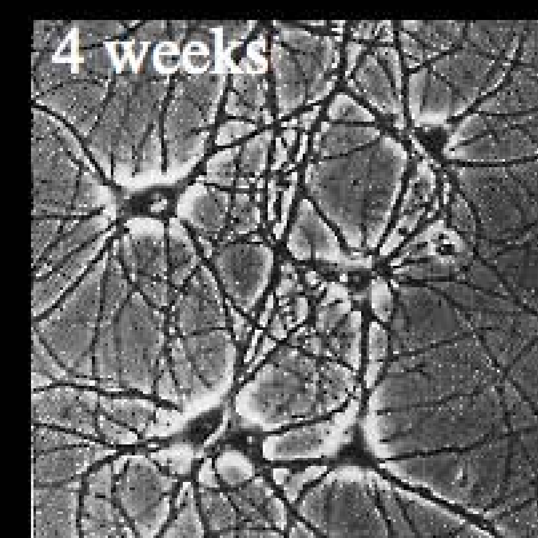




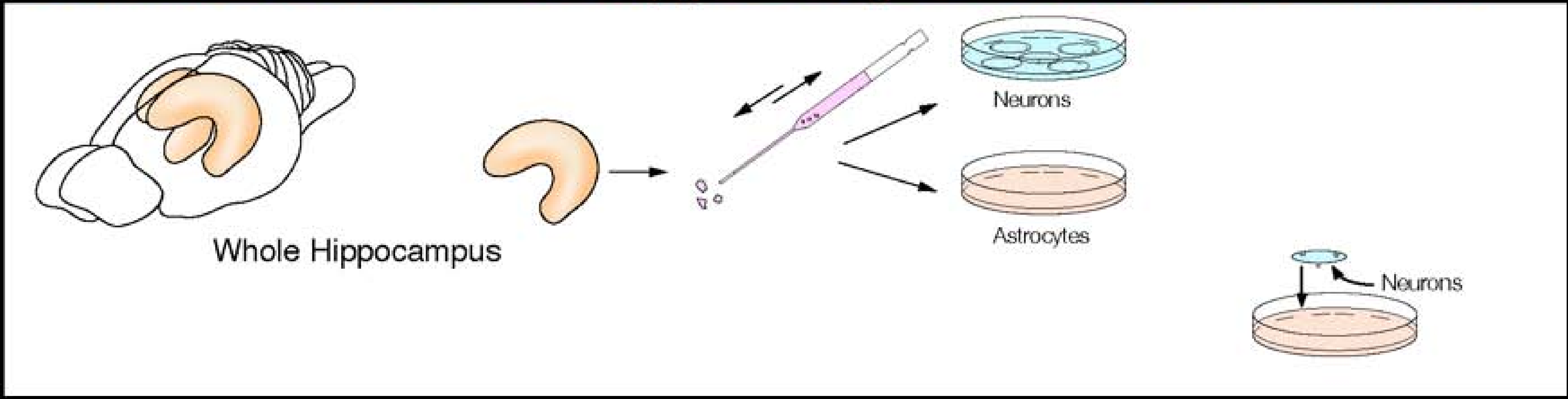


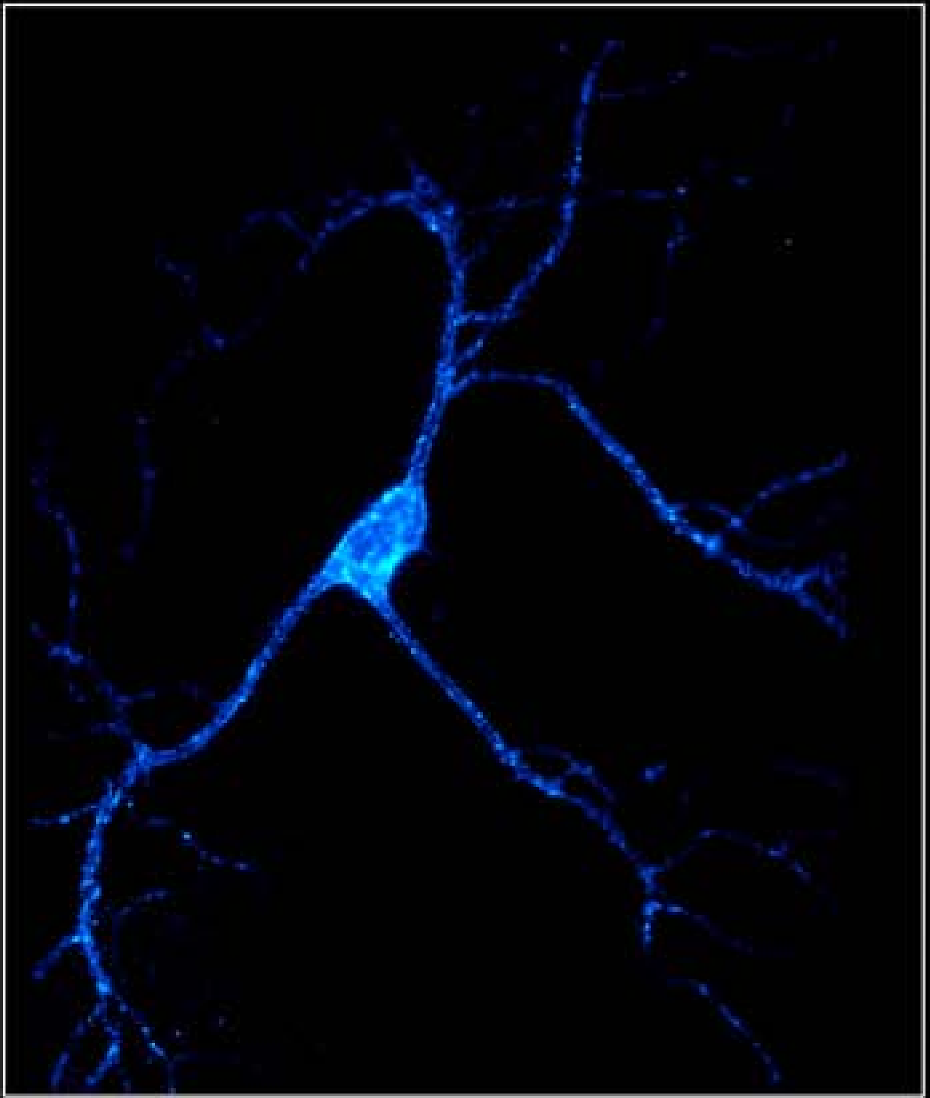
Days in vitro 0,25 0,5 1,5 4 >7





The sandwich model of Hippocampal neurons in culture





Danglot et al (2003), Mol Cell Neurosci. 23:264-278.

C. Verderio et al., Cell. Mol. Life Sci. 55 (1999) 1448–1462.

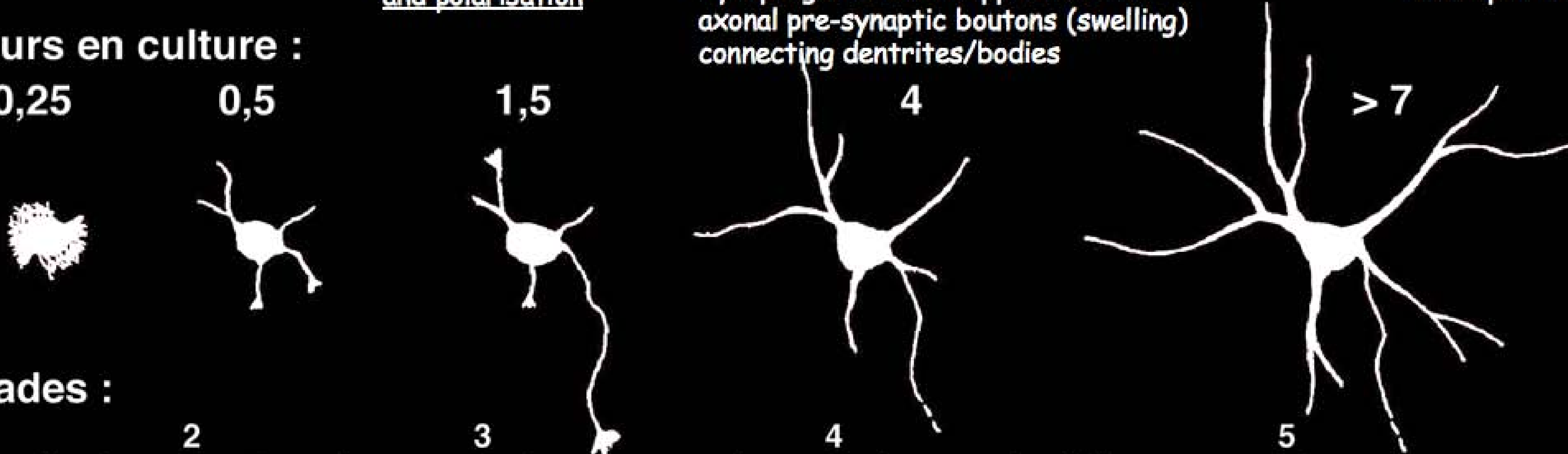
<u>Axonal outgrowth and polarisation</u>

Dentrites outgrowth
Synaptogenesis with appearance of axonal pre-synaptic boutons (swelling) connecting dentrites/bodies

Onset of <u>dentritic spines</u> development

Jours en culture :

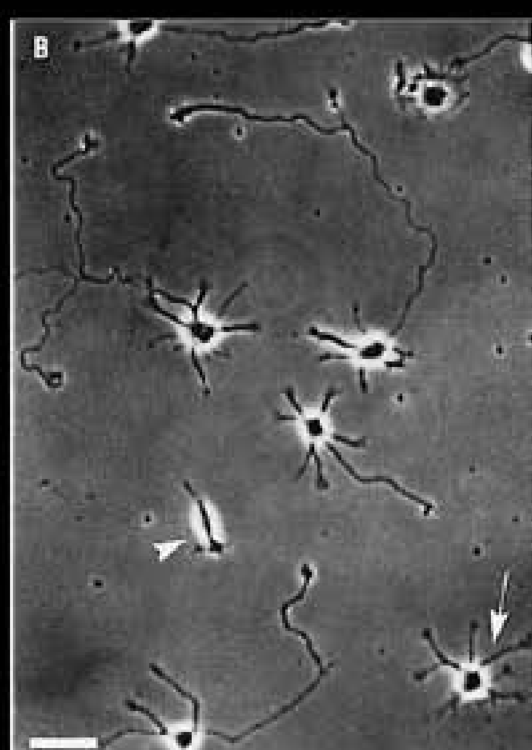
0,25	0,5	1,5	4	> 7

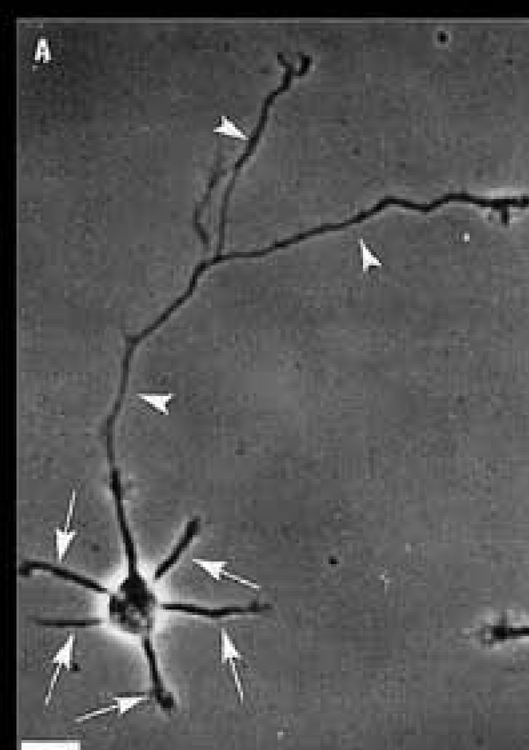


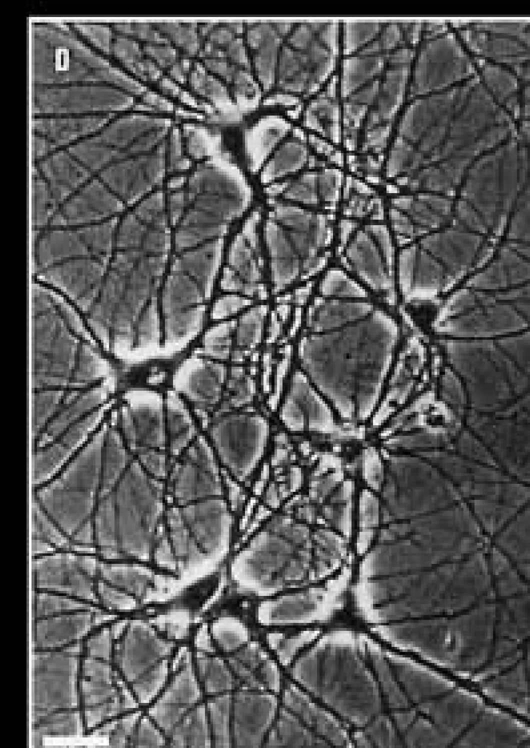
Stades :

1	2	3	4	5
Lamelipodes	Neurites mineurs	Croissance axonale	Croissance dendritique	Maturation

DIV 18-21

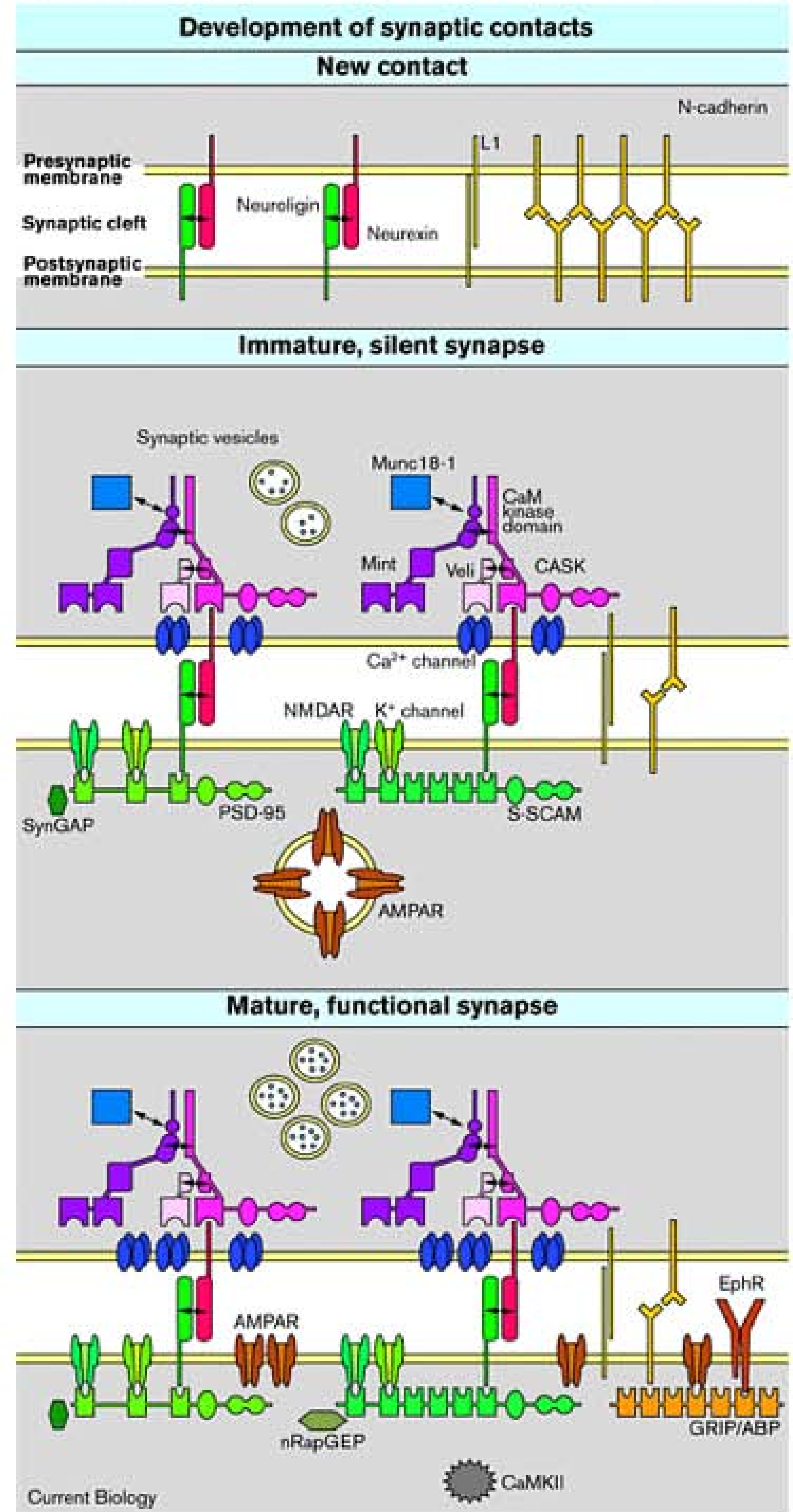




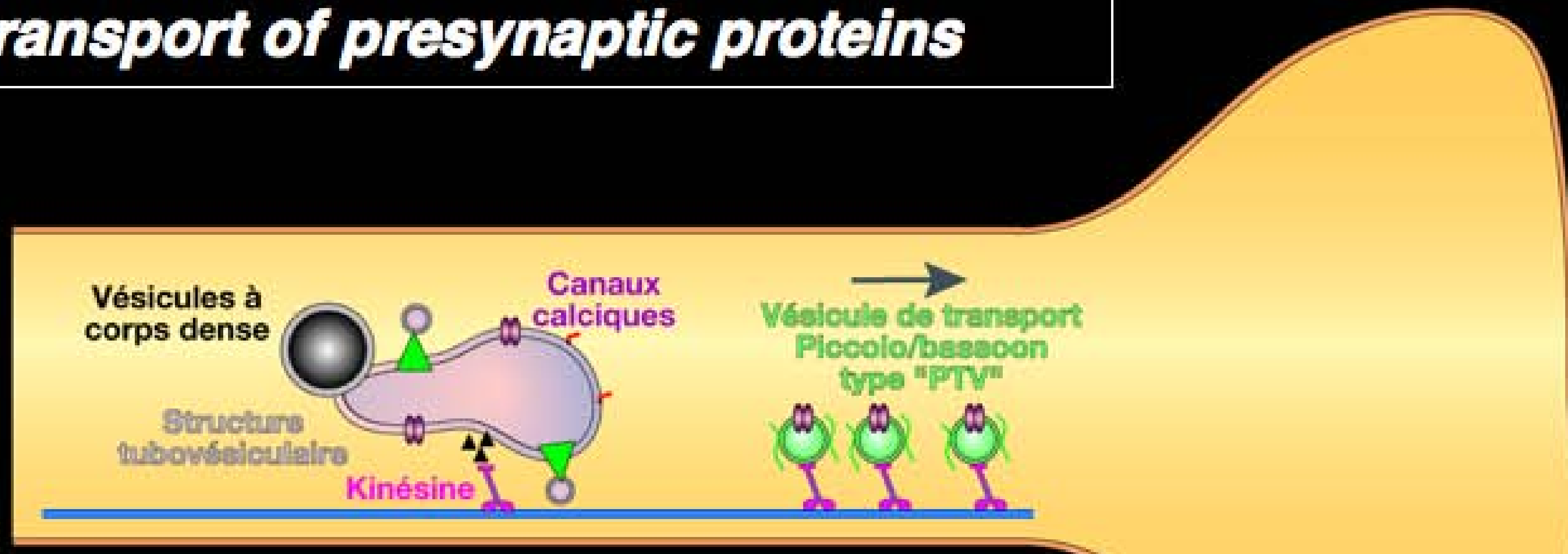


Phase contrast microscopy (Goslin et al., 1977)

Formation of the synapse



Axonal transport of presynaptic proteins



Structures tubovésiculaires

500-1500 nm de diametre

Ahmari et coll., Nat Neur, 2000.

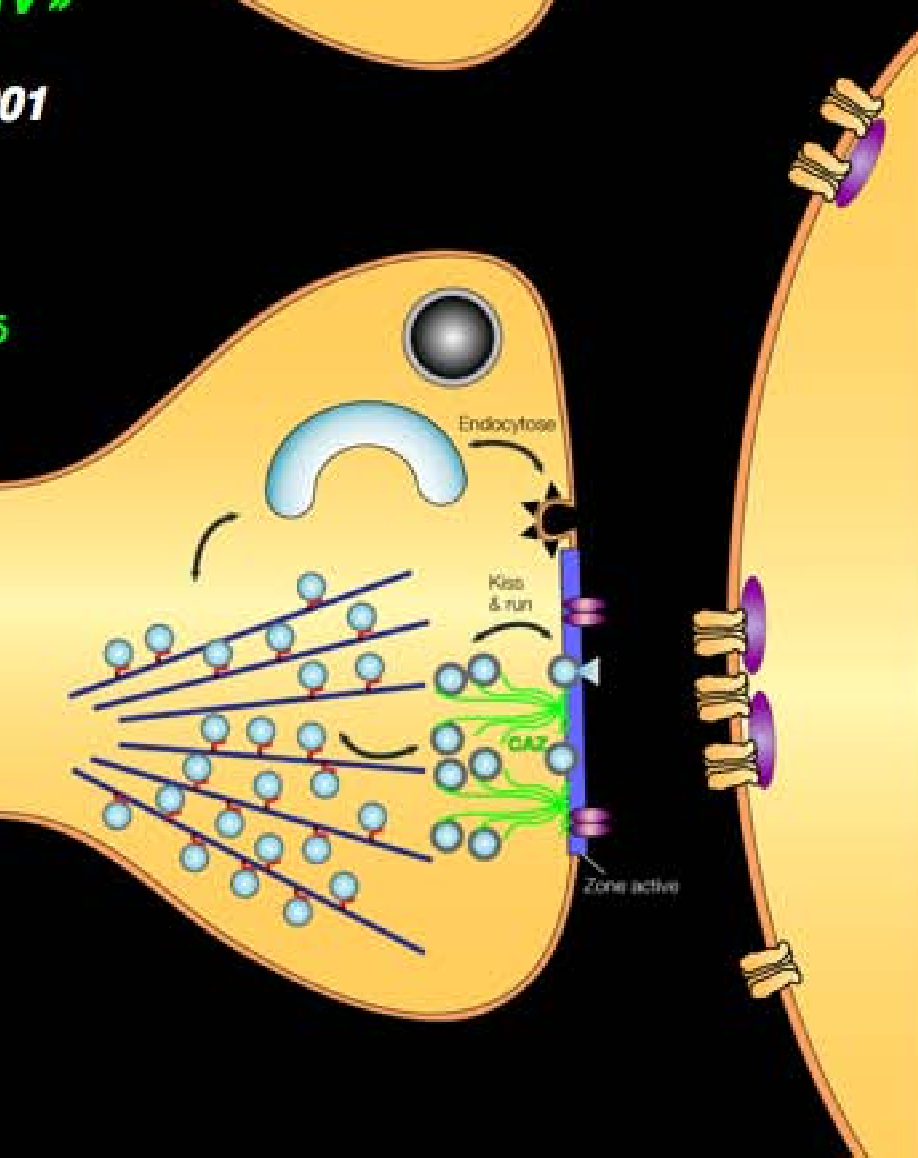
VAMP
SV2
VDCC
Synapsine
amphiphysine

Vésicules de transport Piccolo/ Bassoon: « PTV »

80 nm de diamètre

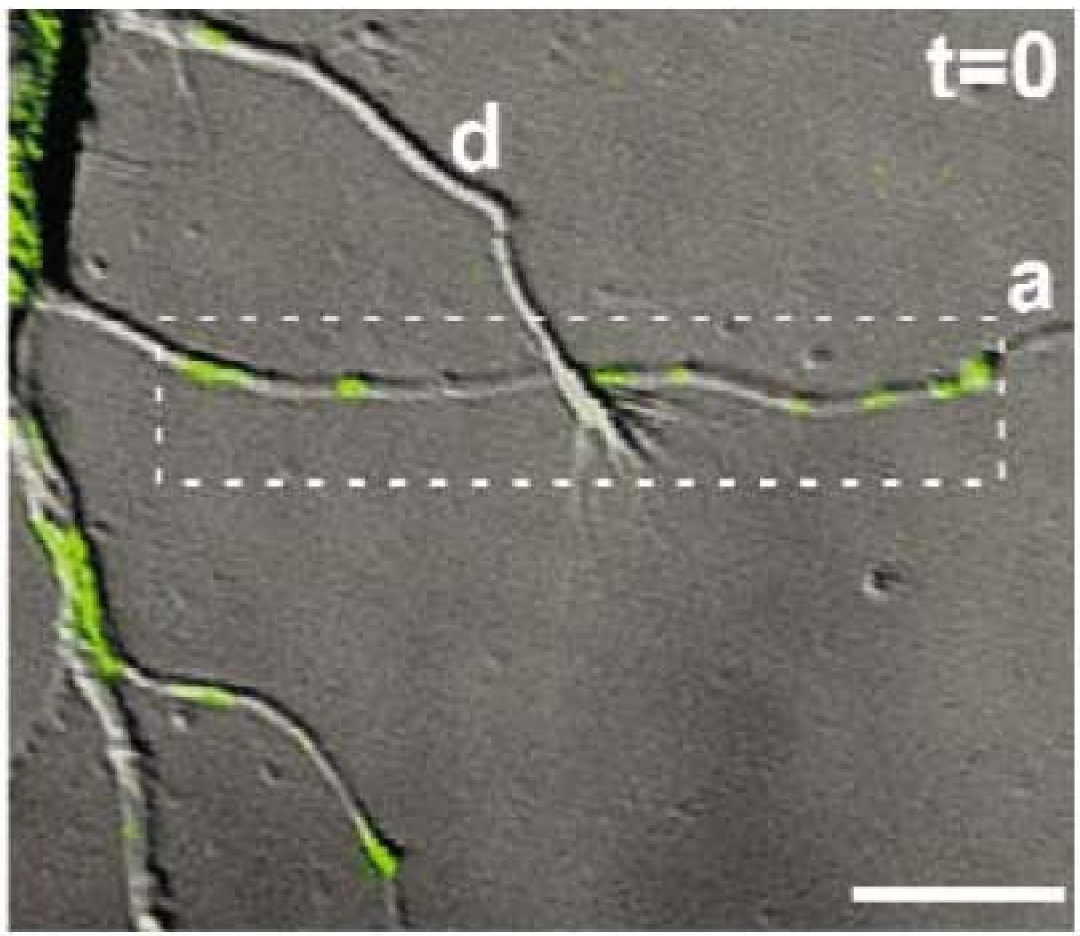
Zhai et al., Neuron, 2001

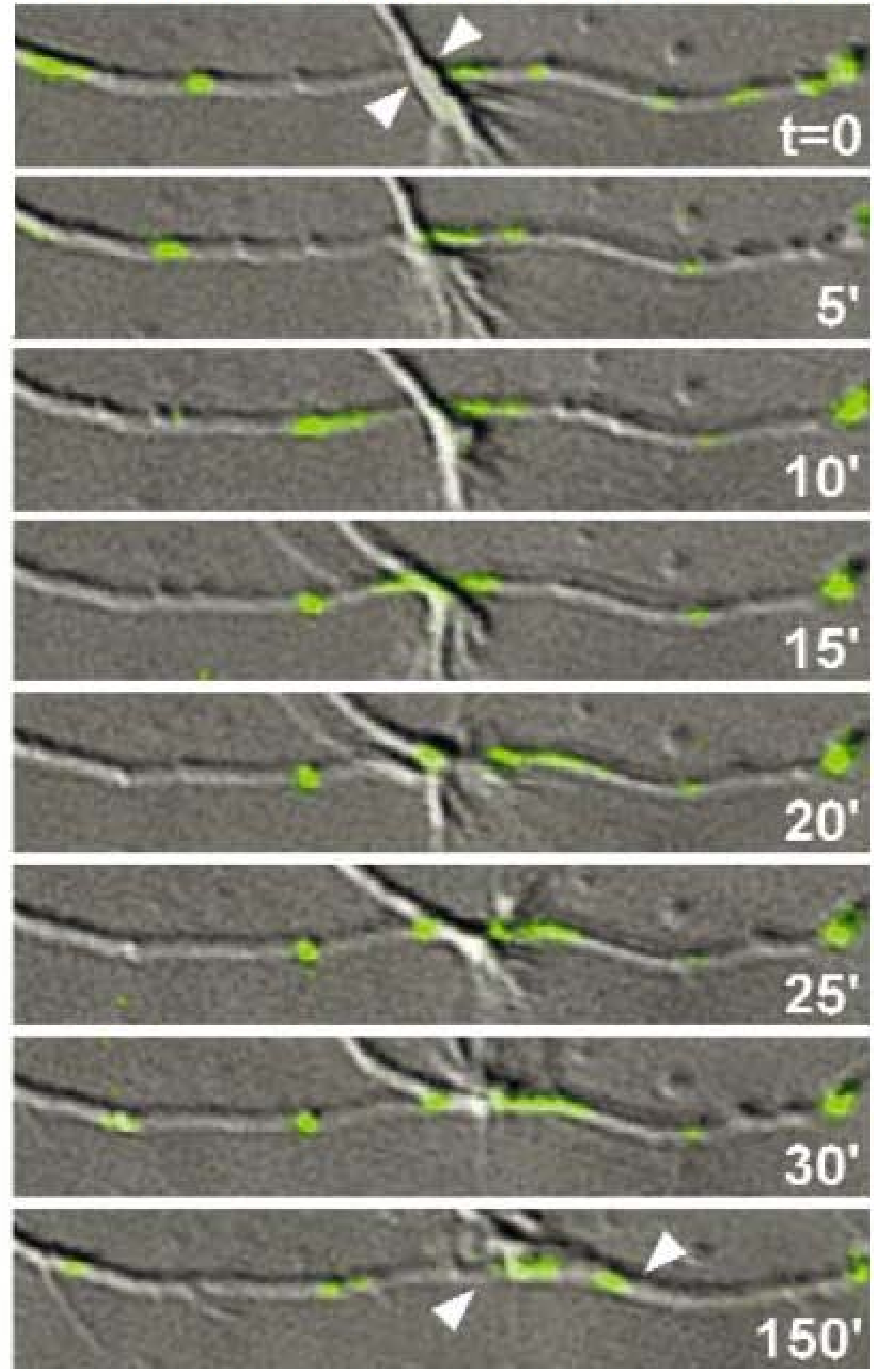
Piccolo
Bassoon
RIM, Munc13, VDCC
Munc18, Syntaxine, SNP25
N-Cadhérine, …



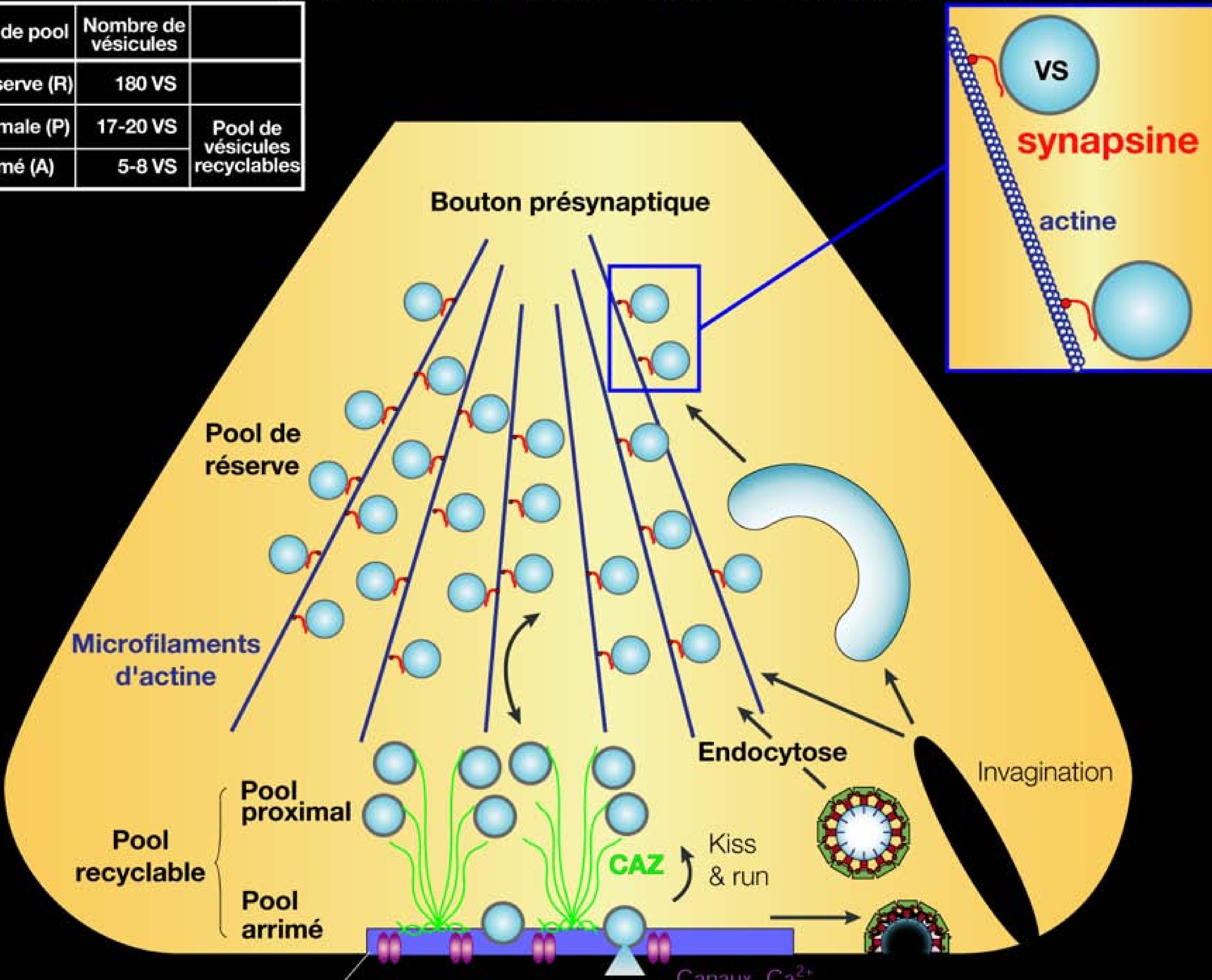
Assembly of presynaptic active zones from cytoplasmic transport packets

Susanne E. Ahmari, JoAnn Buchanan and Stephen J Smith



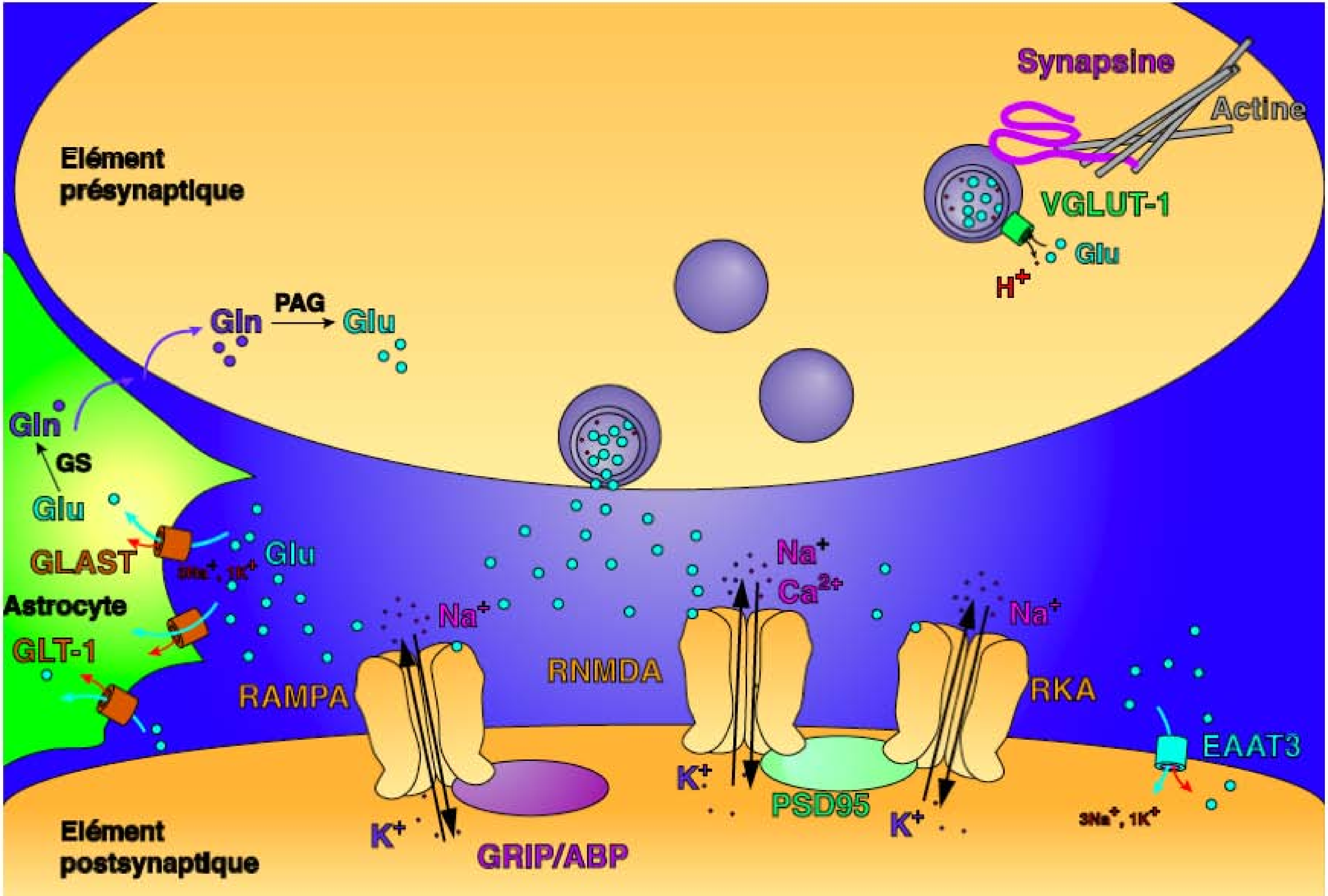


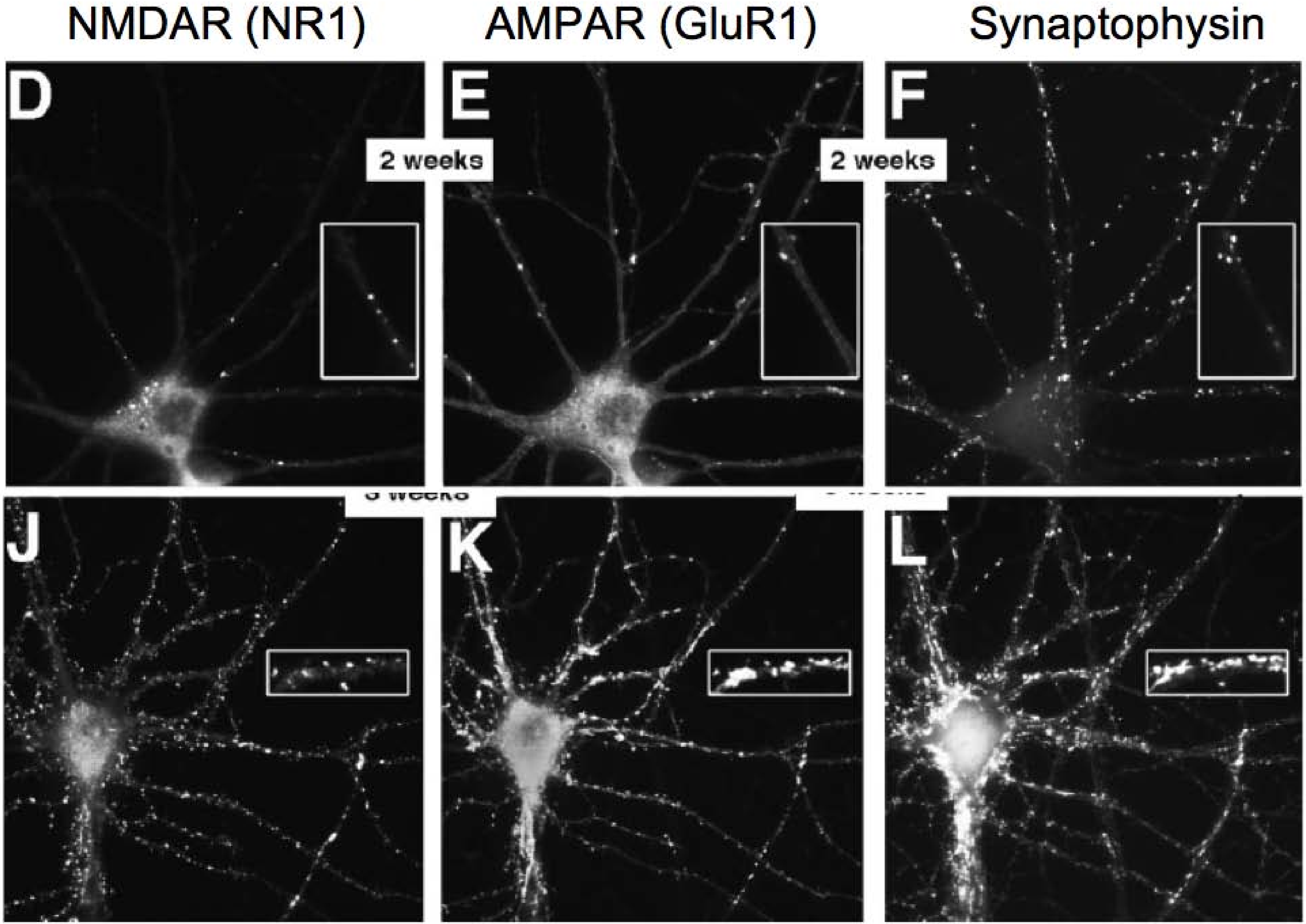
Type de pool	Nombre de vésicules	
de réserve (R)	180 VS	
proximale (P)	17-20 VS	Pool de vésicules recyclables
arrimé (A)	5-8 VS	



Modifié d'après Current Opinion in Neurobiology 2000, 10:321–327 et Natrure Review Molecular Cell Biology, 2003, 4:127-139.

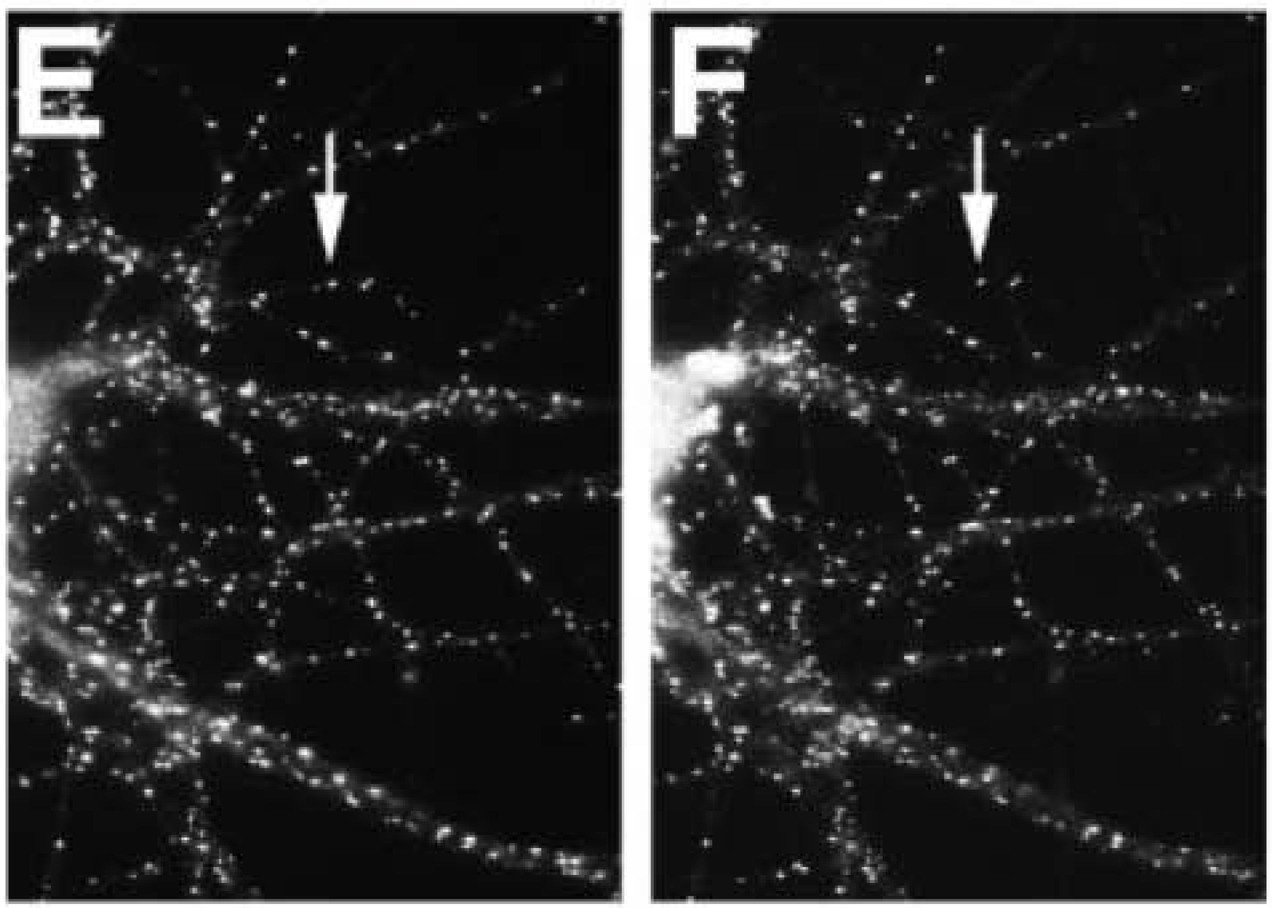
Glutamatergic synapse

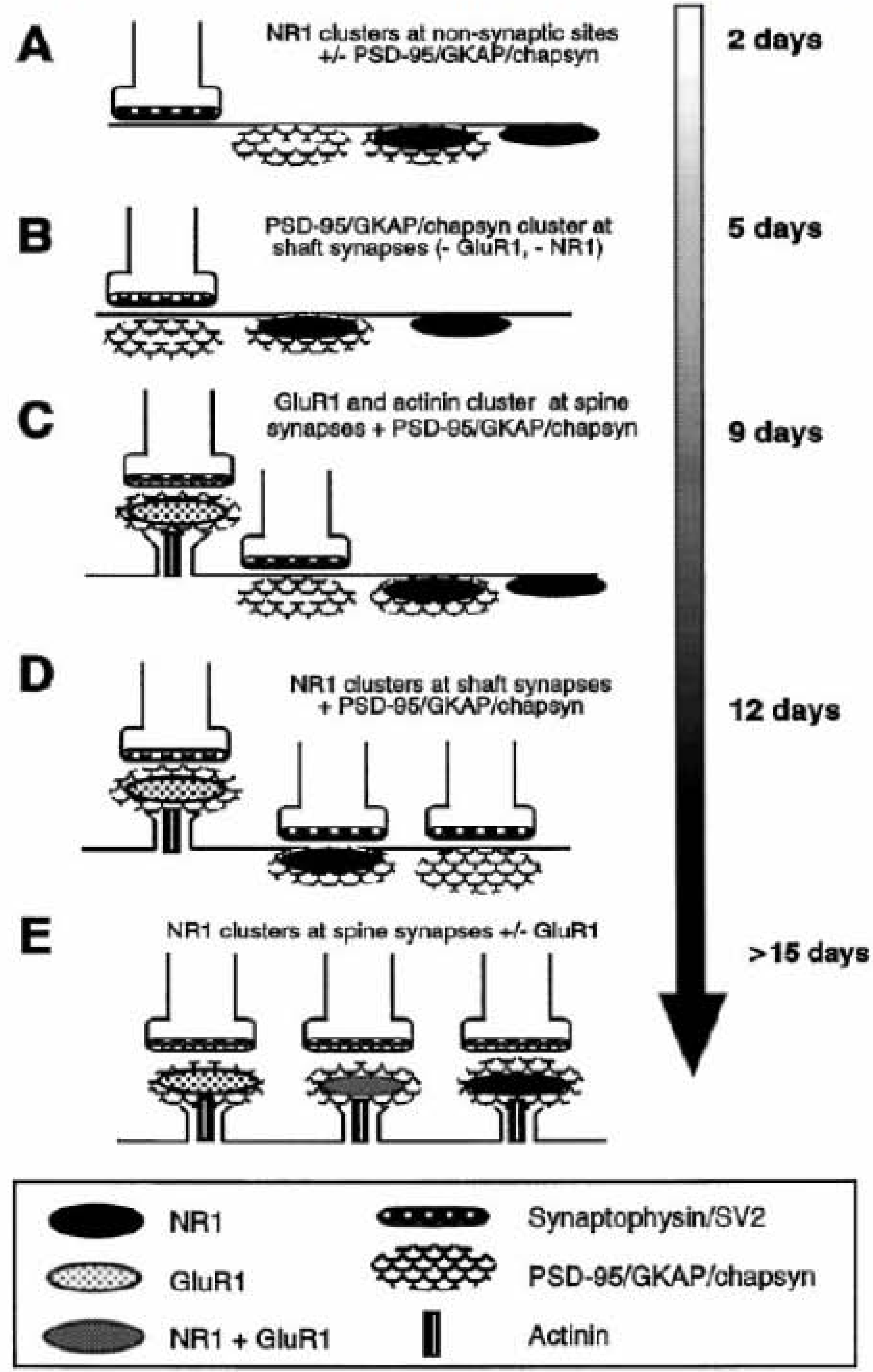




The Journal of Neuroscience, February 15, 1998, *18*(4):1217–1229

NMDAR (NR1) PSD 95





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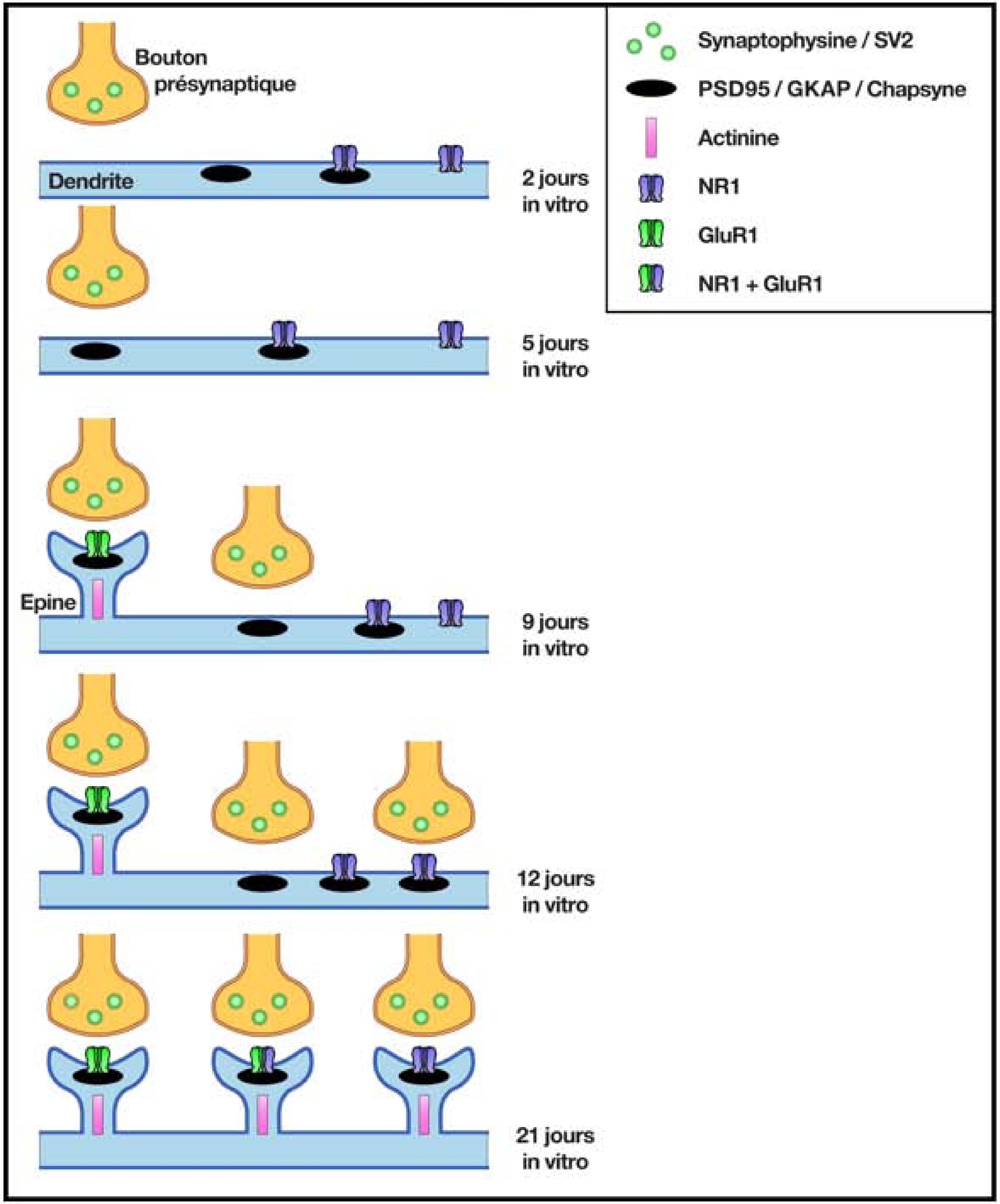
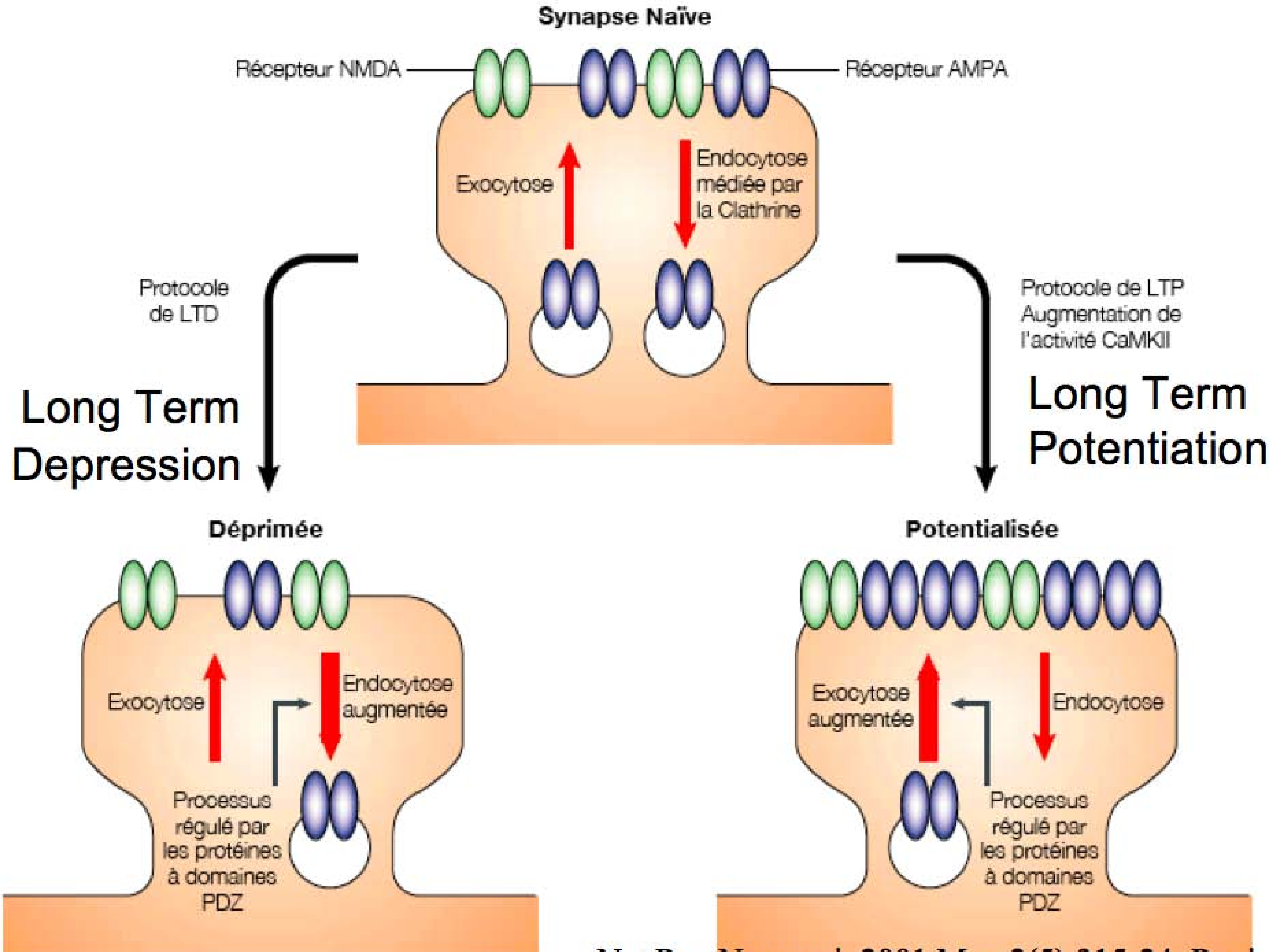
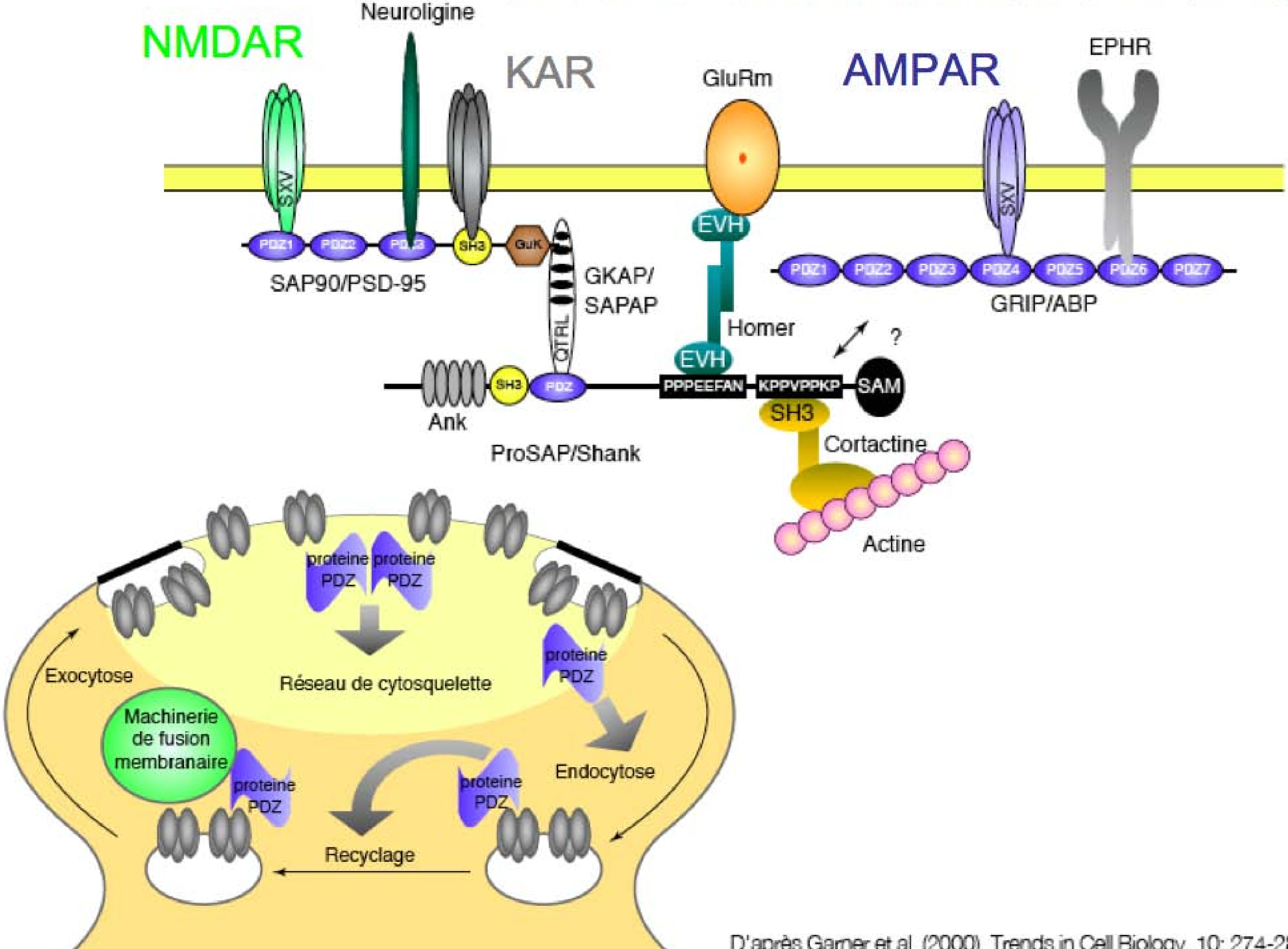


Danglot PhD report. (2004)



Nat Rev Neurosci. 2001 May;2(5):315-24. Review.



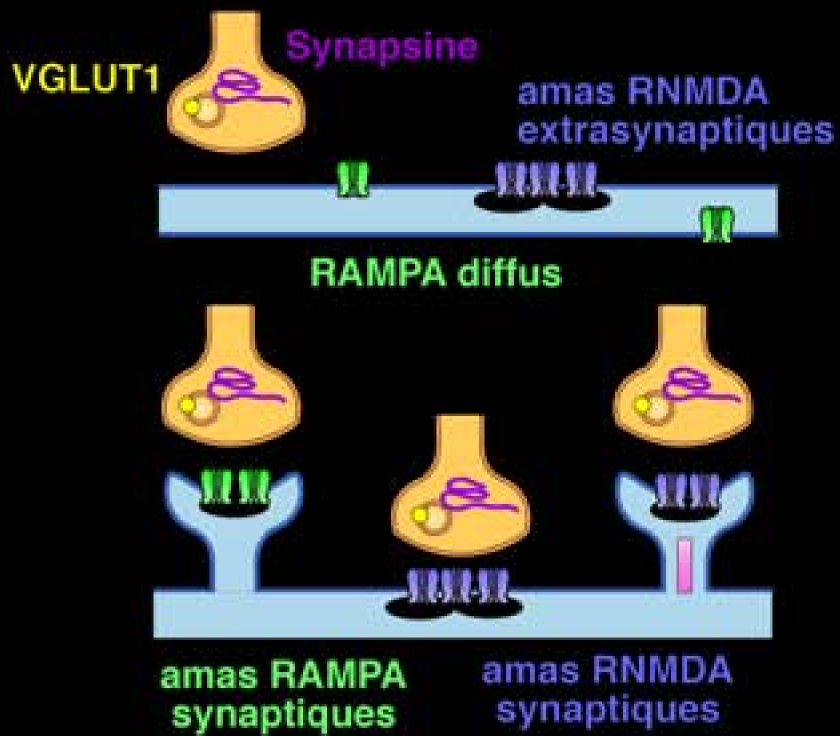
D'après Garner et al. (2000), Trends in Cell Biology, 10: 274-280.

Targeting of post-synaptic proteins

Synapse excitatrice
hippocampe

Laboratoire A.M. Craig

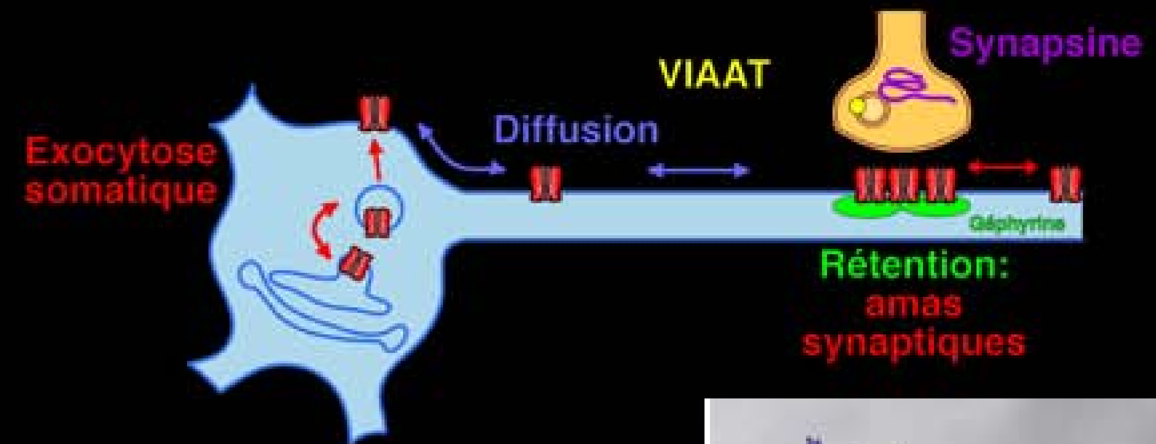
Rao et al., J. Neurosci., 2000
Rao et al., J. Neurosci., 2000

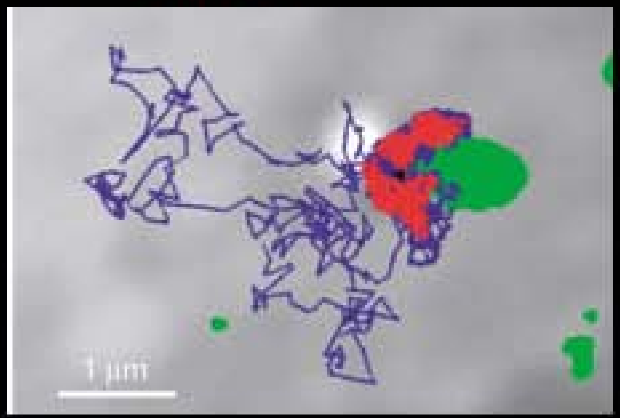


Synapse inhibitrice
moelle épinière

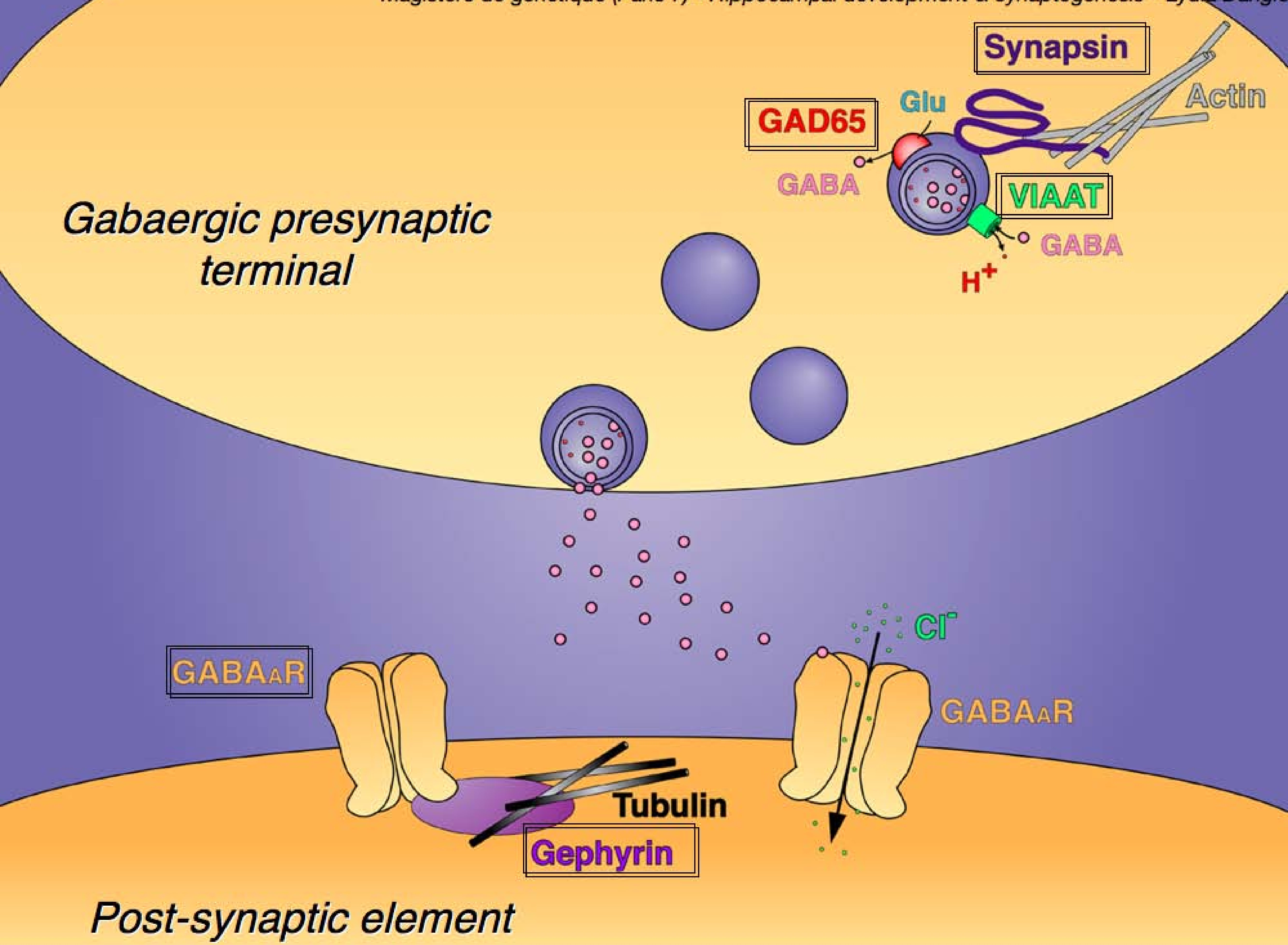
Laboratoire A.Triller

Rosenberg et al., J. Neurosci, 2000
Meier et al, JCS, 2000
Meier et al., Nat. Neur., 2001

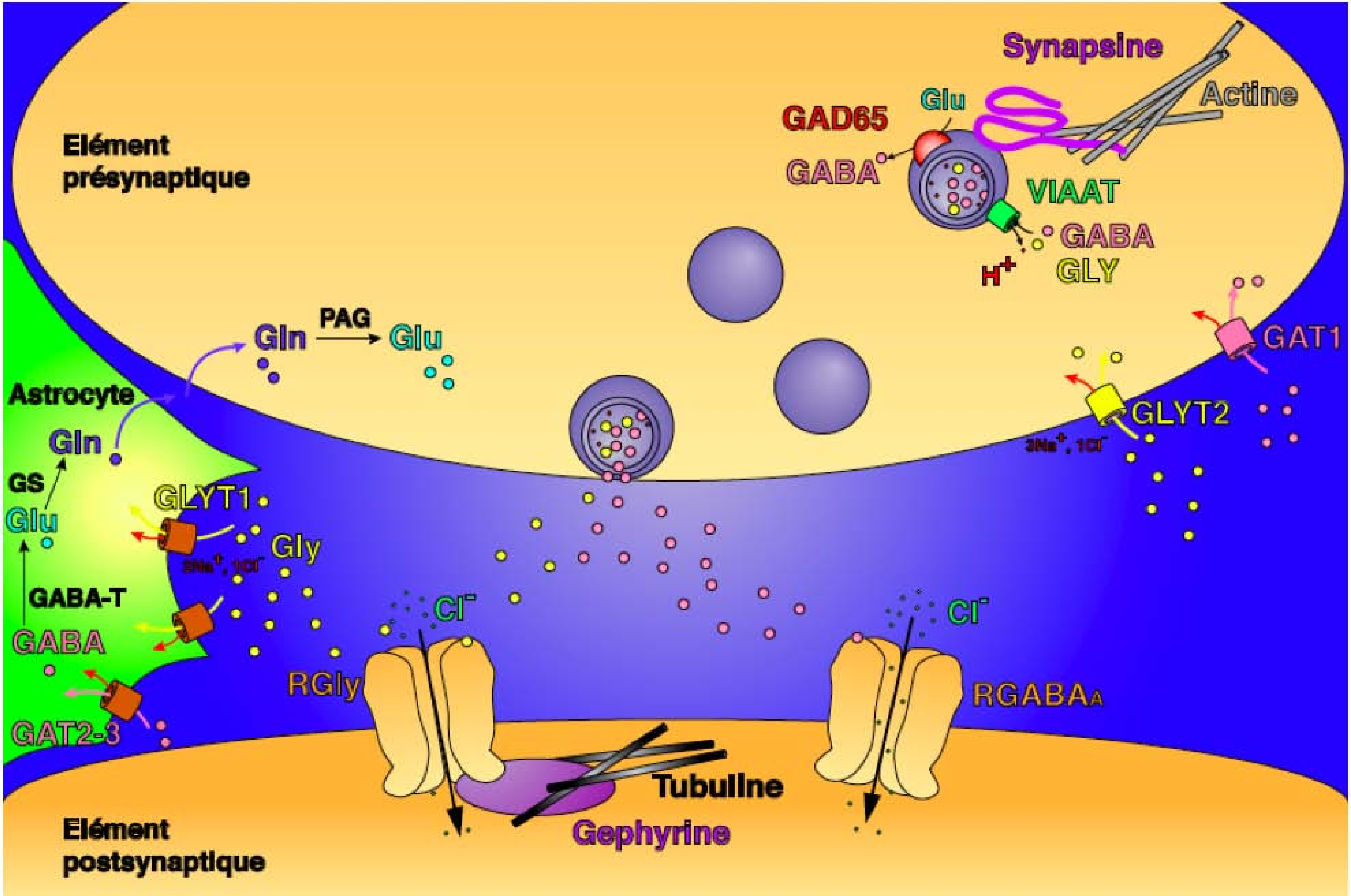


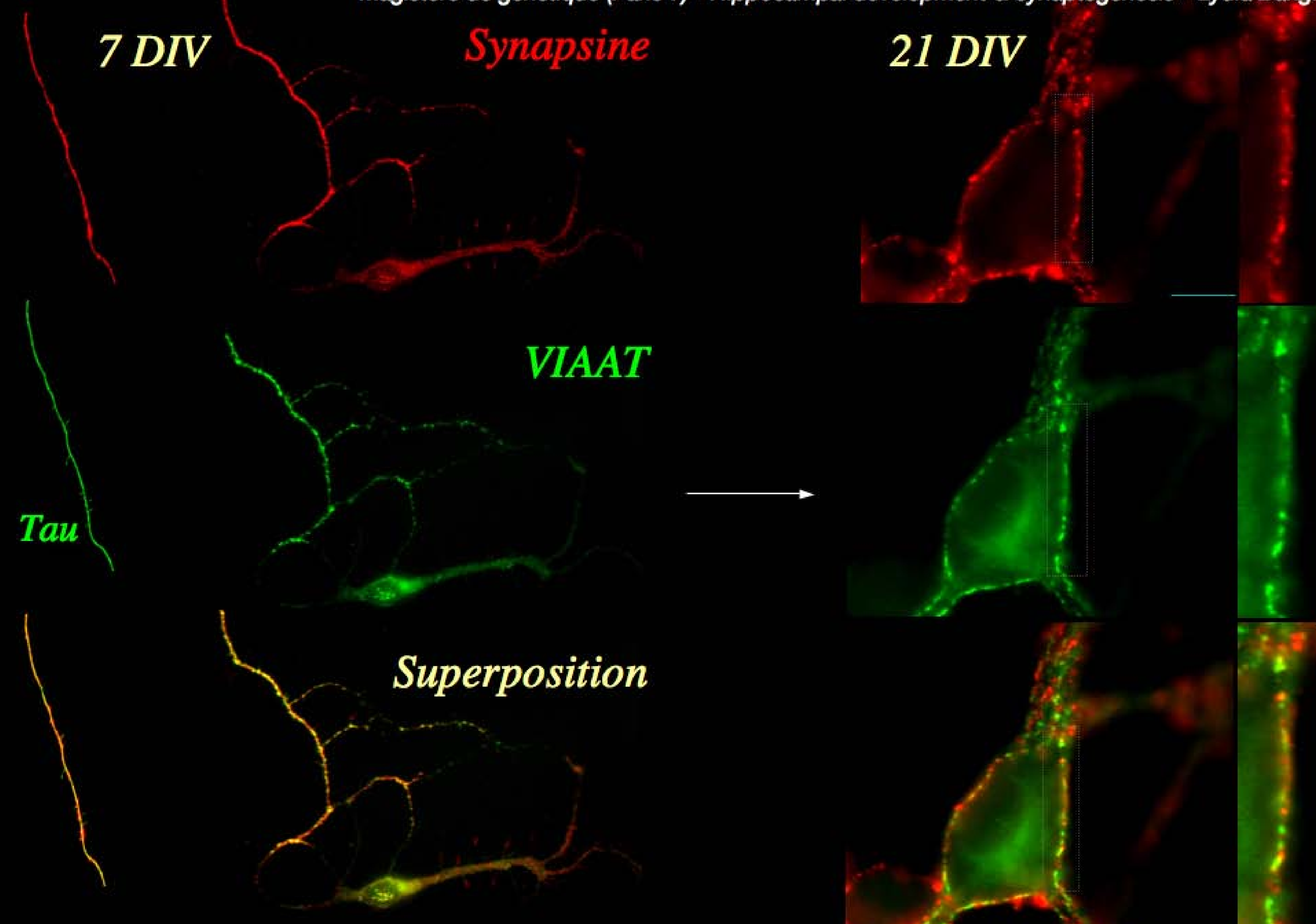


Synapse inhibitrice
hippocampe
?


Synapsin
Actin
Glu
GAD65
GABA
VIAAT
GABA
H^+
Gabaergic presynaptic terminal
Cl^-
GABAAR
GABAAR
Tubulin
Gephyrin
Post-synaptic element

GABAergic synapse

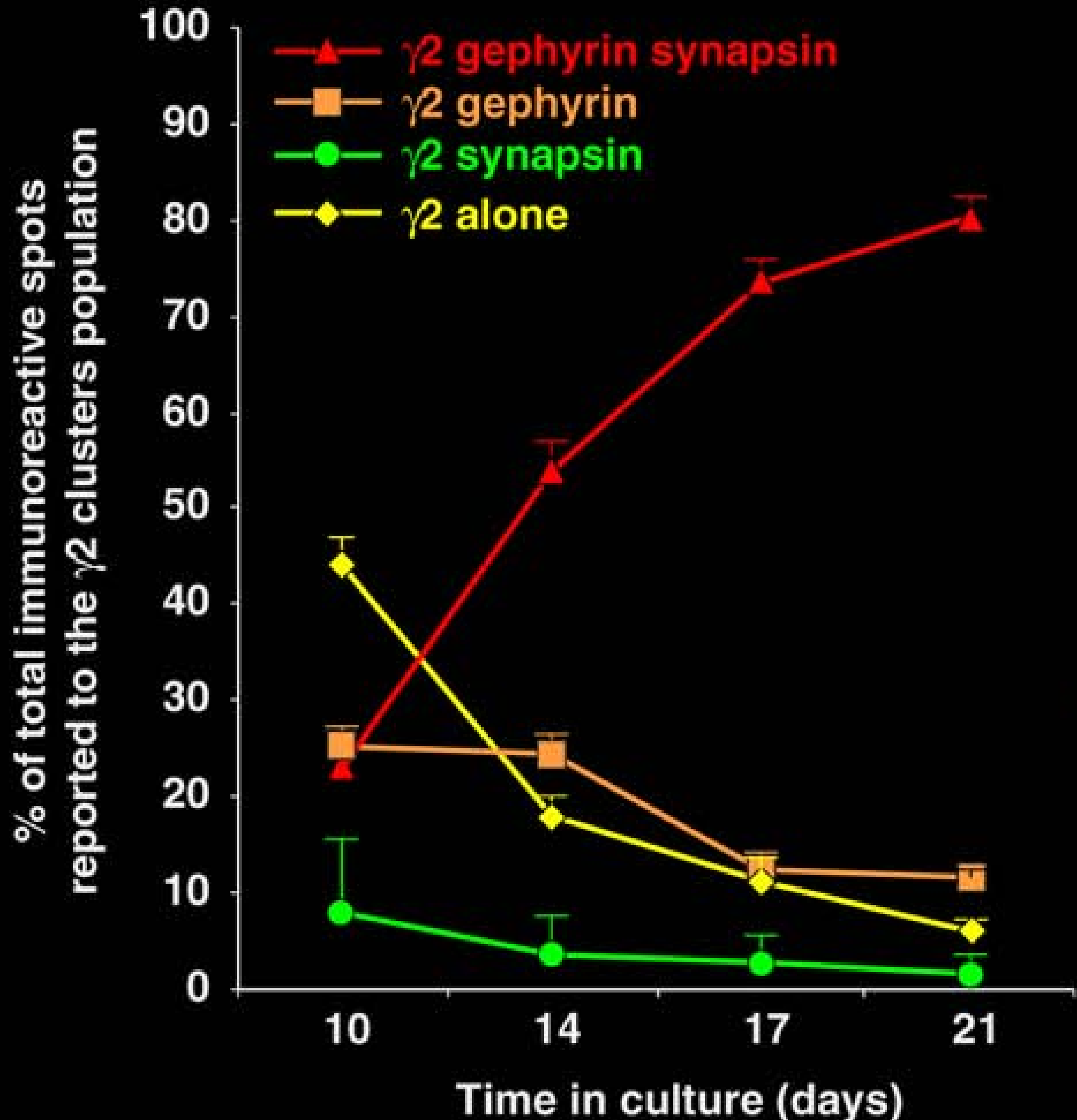


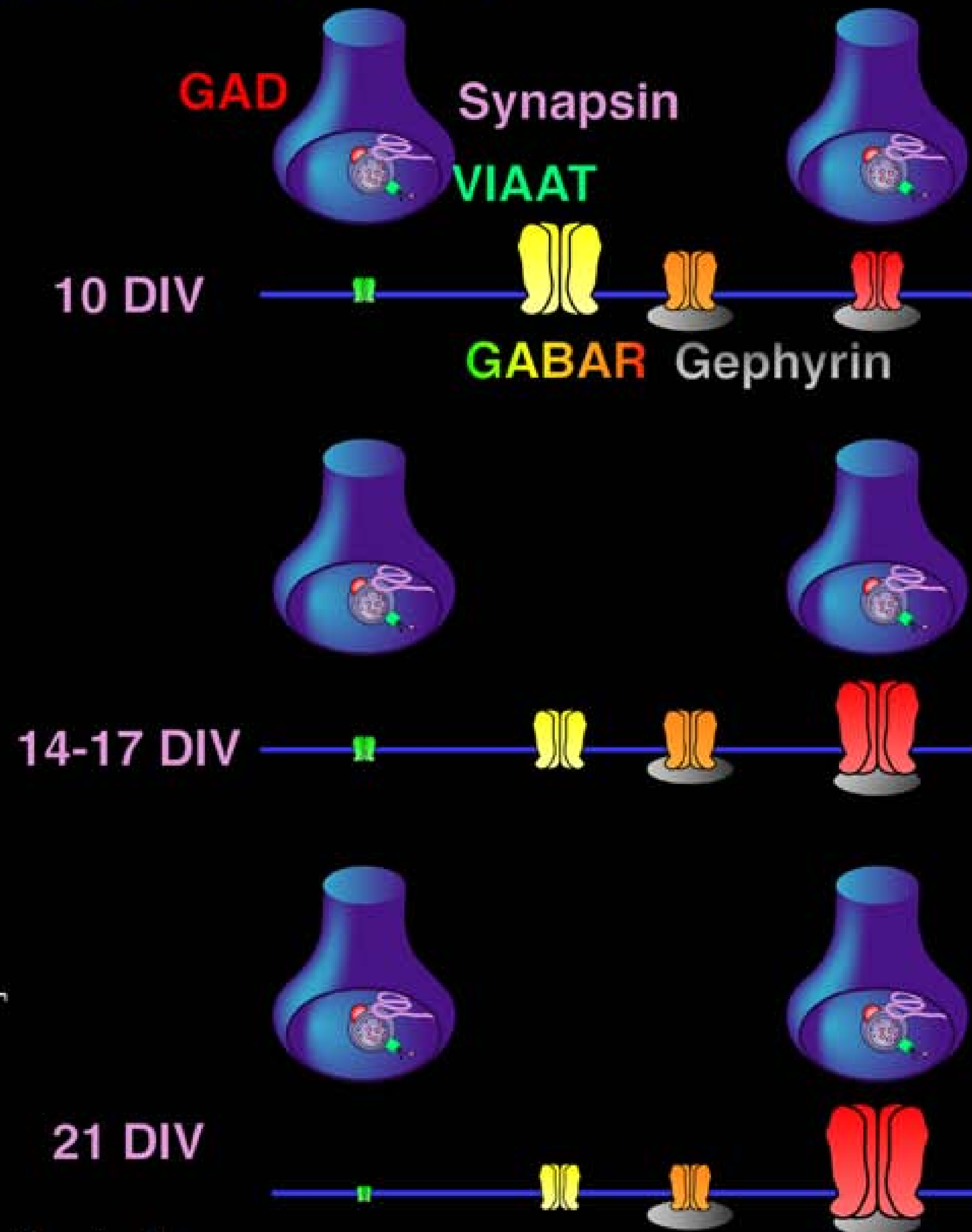


Danglot et al. Mol cell Neurosci. (2003)

VIAAT: Axonal diffuse expression and clustering after 10 dais in vitro (DIV).

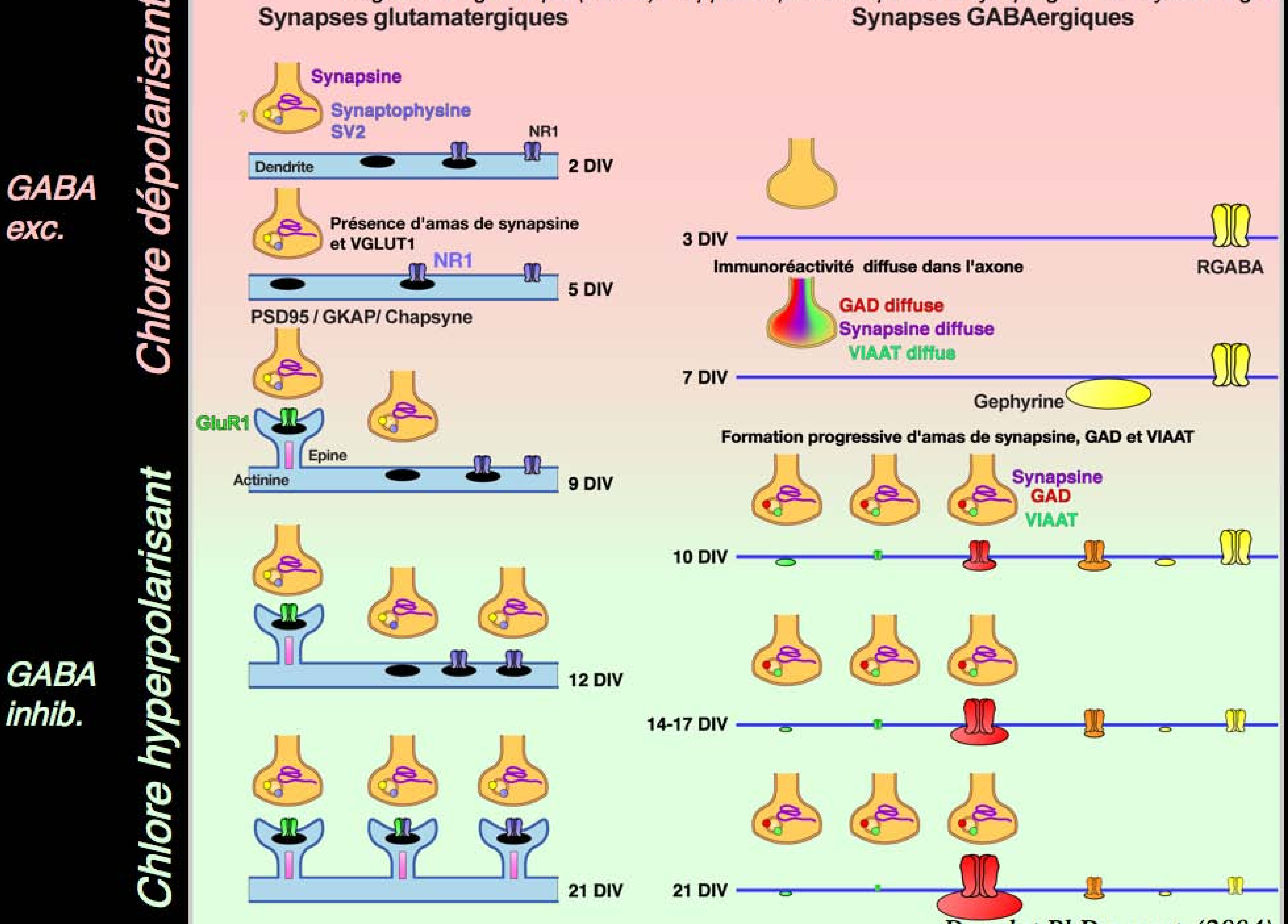
Gephyrin and GABAAR γ2 associates before being detected at synapses





Gephyrin is dispensable for GABAAR γ2 clustering.

Danglot et al. Mol cell Neurosci. (2003)



Danglot PhD report. (2004)

Hippocampal development & Synaptogenesis

1. **Introduction to neuroanatomy**
   - Neurulation
   - Differenciation : Forebrain-Midbrain-Hindbrain
   - Major structures of the brain
2. **Hippocampus & the limbic system**
   - Localization in human and rodents
   - General function
   - Connections and cellular populations
3. **Formation of the hippocampus and dentate gyrus**
   - Migration of excitatory neurons
     - pyramidal cells & granule cells
   - Migration of inhibitory interneurons
4. **Dissociated hippocampal neurons in culture**
   - The sandwich model of Gary Banker
   - Acquisition of neuronal polarity
   - Synaptogenesis

Module « Cellular Neurobiology & Development »
Magistère Européen de Génétique
UFR Sciences du Vivant - Université Denis Diderot Paris VII
22 septembre 2008

Lydia Danglot
Institut Jacques Monod CNRS 7592
Equipe Avenir Inserm T. GALLI
danglot@ijm.jussieu.fr

Some interesting handbooks …

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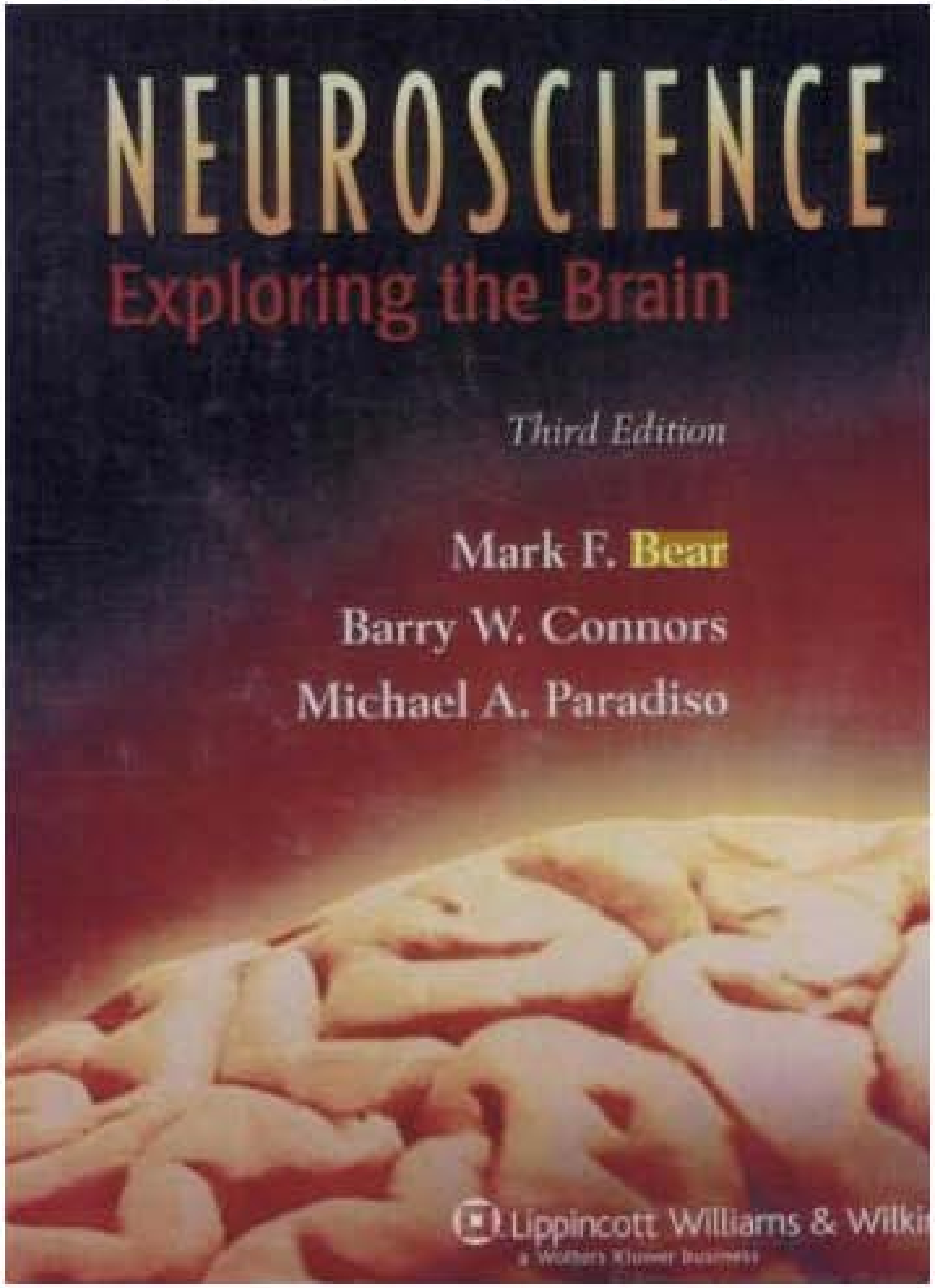

Neuroscience: Exploring the Brain
de Mark F. Bear, Barry W. Connors, Michael A. Paradiso
2006 - 857 pages
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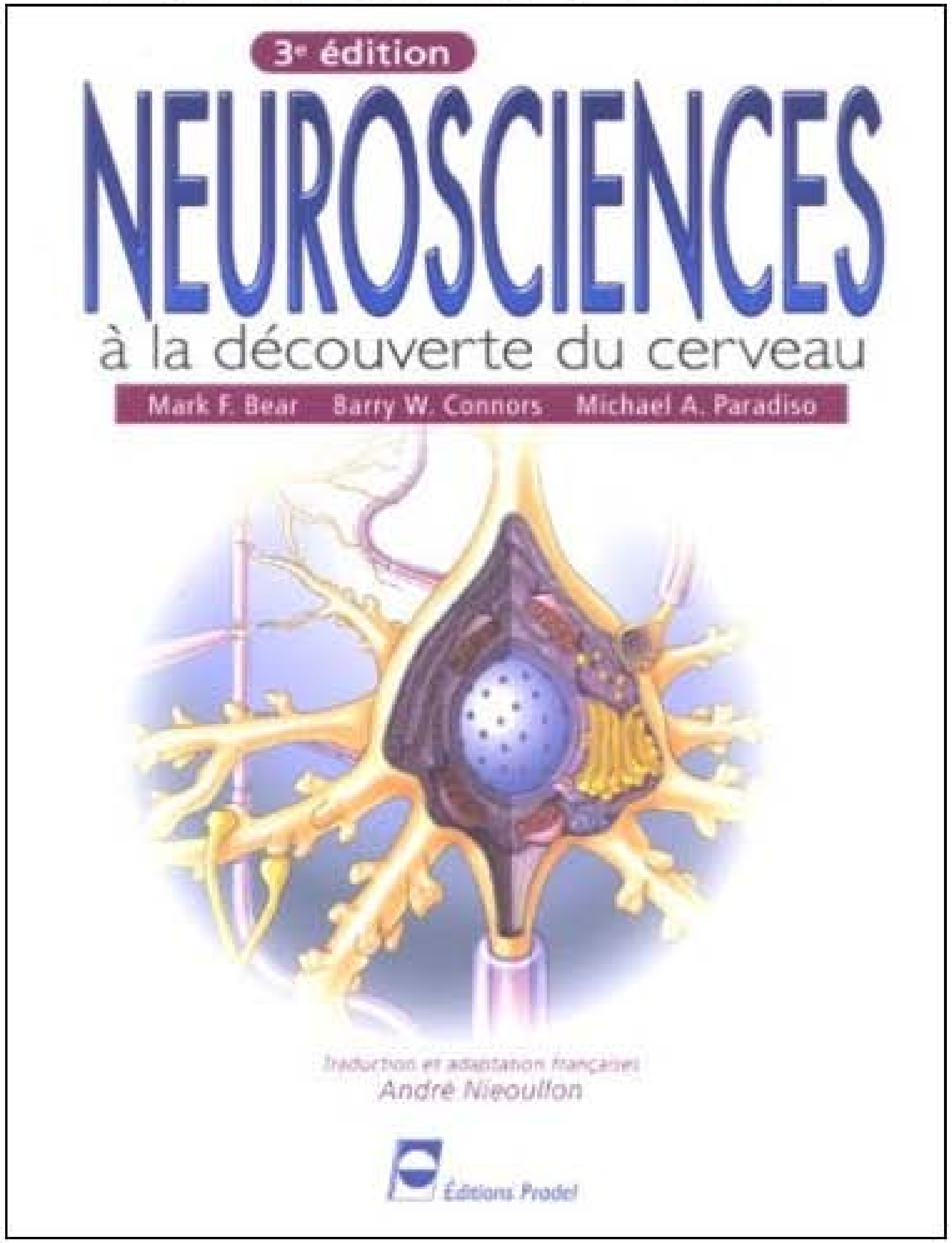

Neurosciences : A la découverte du cerveau
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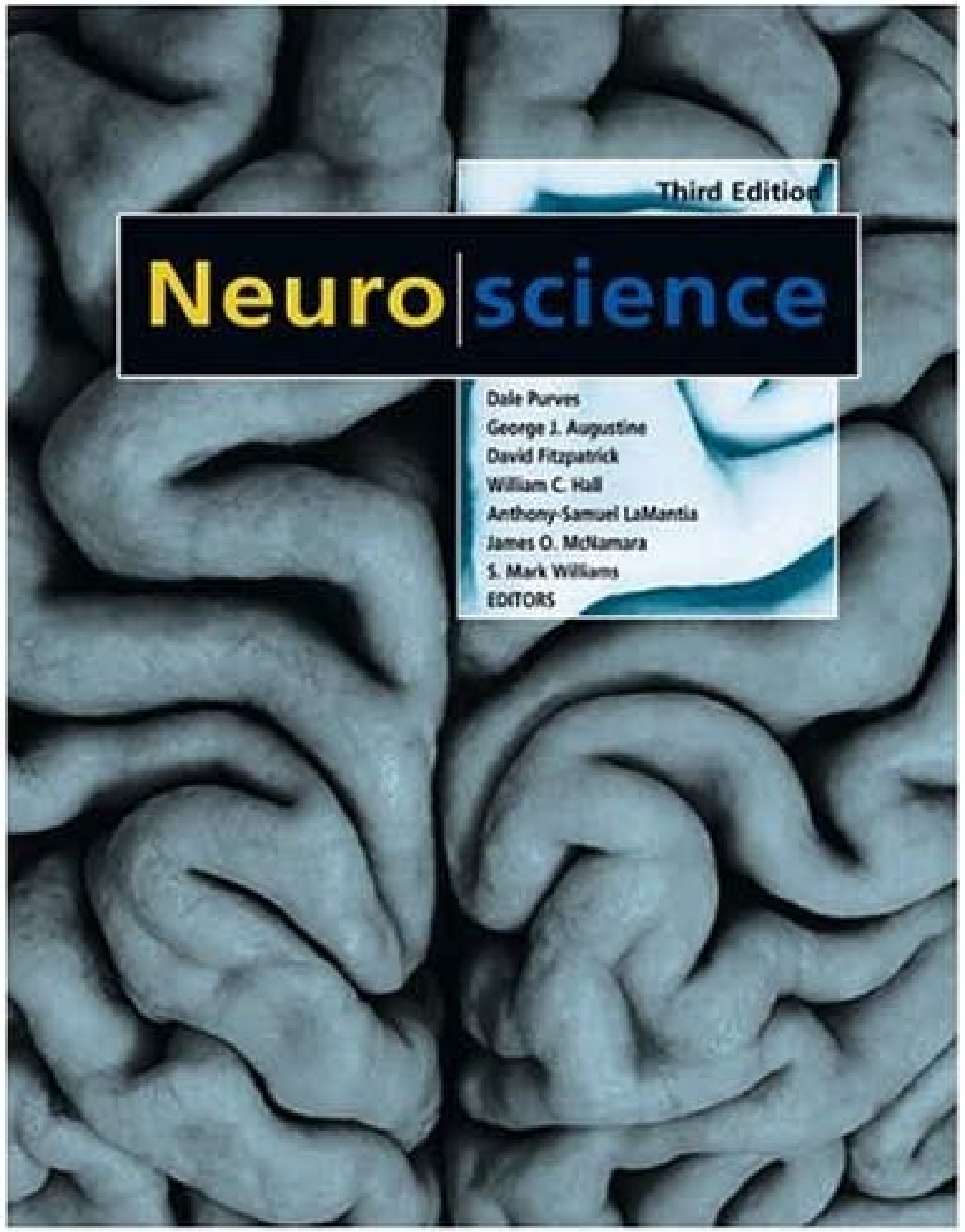

Neuroscience
De Dale Purves, George J. Augustine, David Fitzpatrick

Published by Sinauer Associates, 2004

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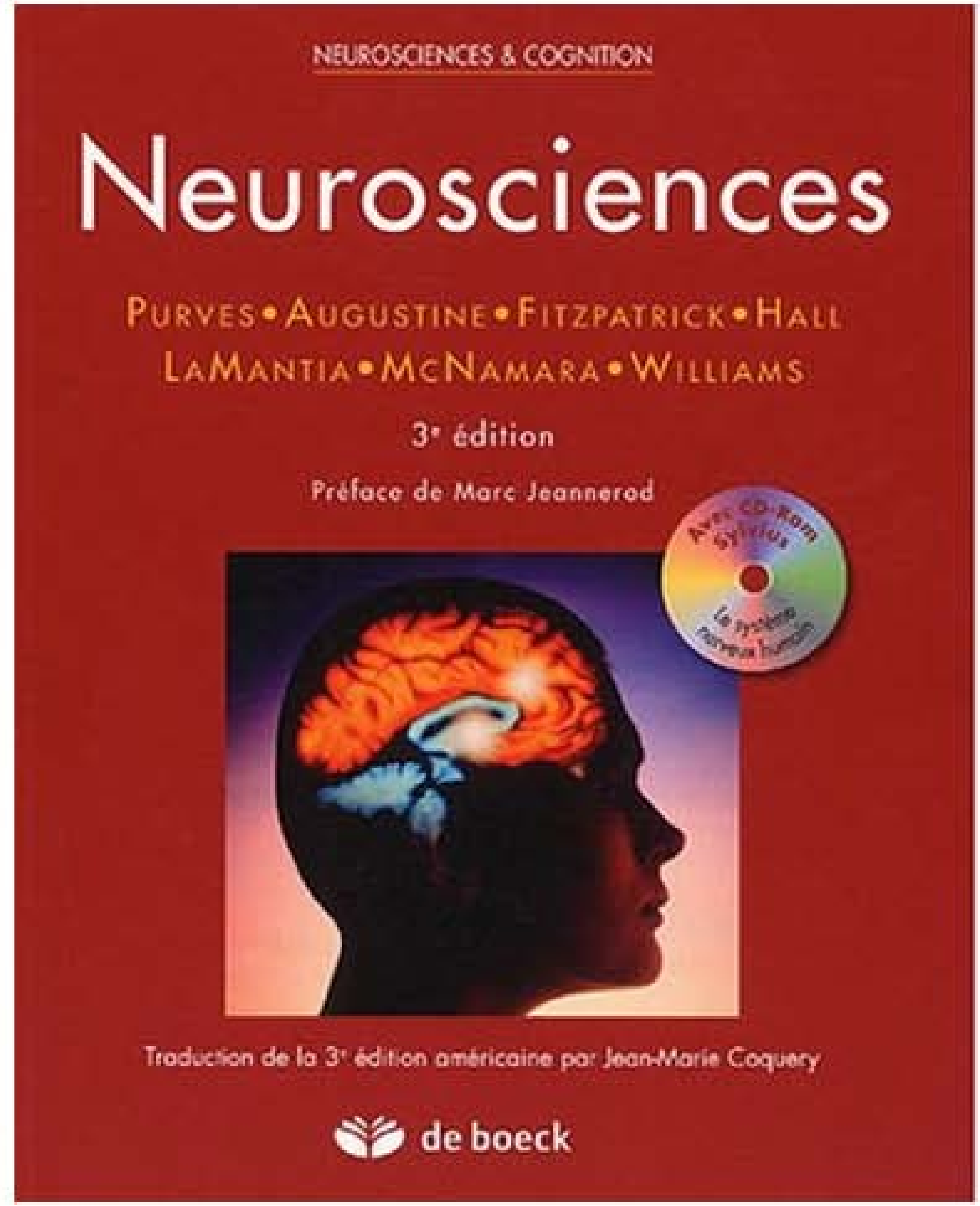

Neurosciences:
De Dale Purves, George J. Augustine, David Fitzpatrick
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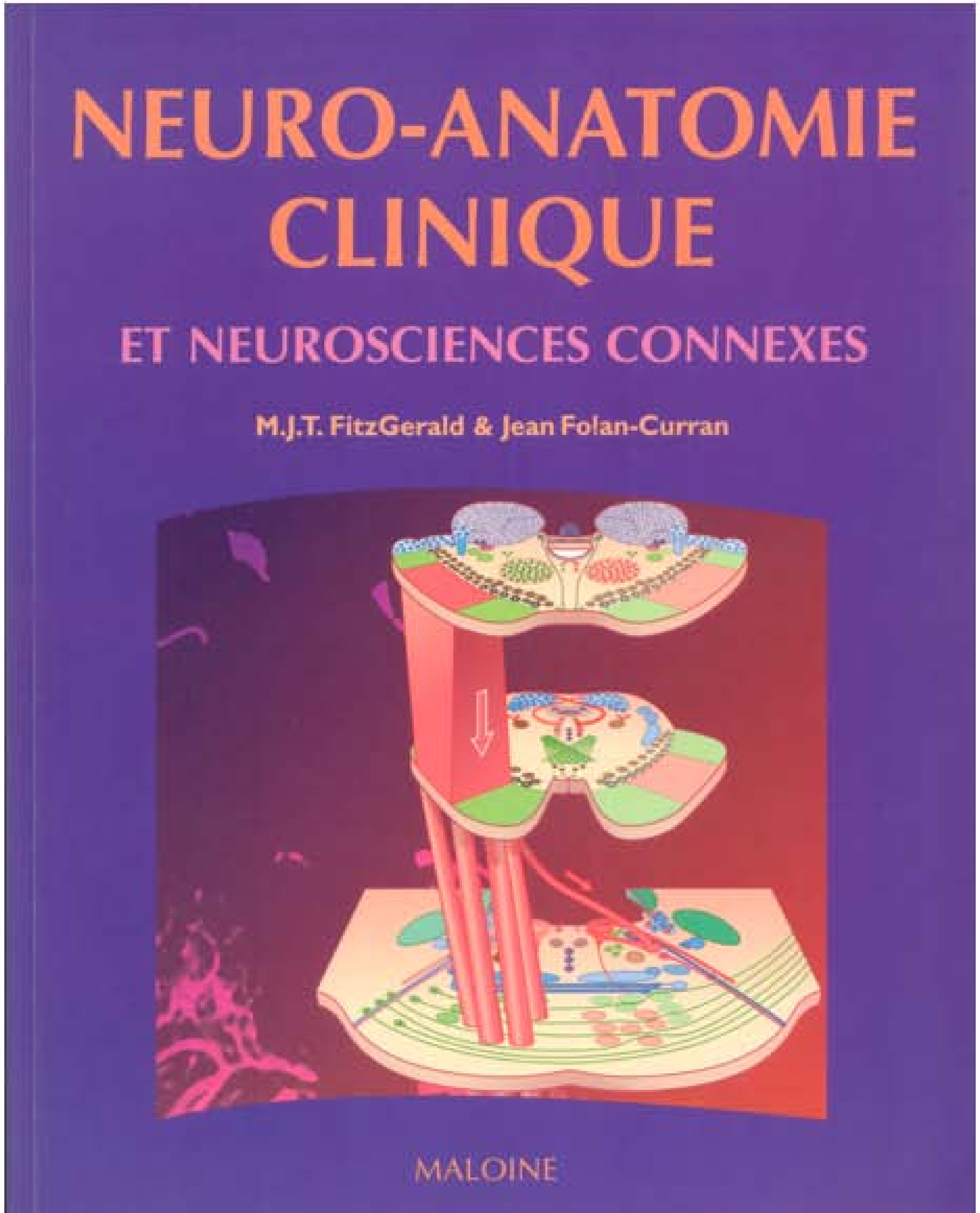

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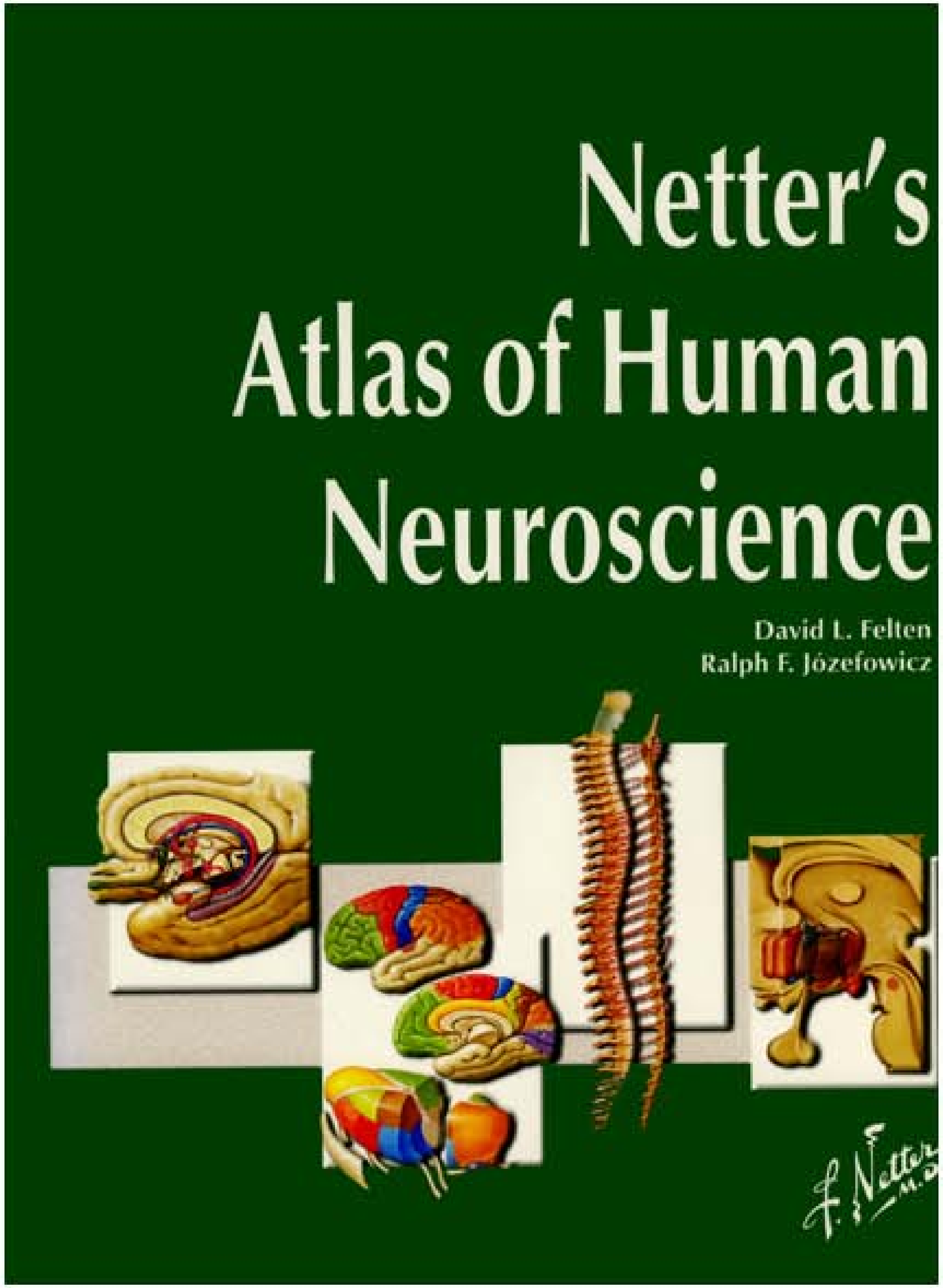

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