Comprehensive Cellular-Resolution Atlas of the Adult Human Brain

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ABSTRACT

Detailed anatomical understanding of the human brain is essential for unraveling its functional architecture, yet current reference atlases have major limitations such as lack of whole-brain coverage, relatively low image resolution, and sparse structural annotation. We present the first digital human brain atlas to incorporate neuroimaging, high-resolution histology, and chemoarchitecture across a complete adult female brain, consisting of magnetic resonance imaging (MRI), diffusion-weighted imaging (DWI), and 1,356 large-format cellular resolution (1 μm/pixel) Nissl and immunohistochemistry anatomical plates. The atlas is comprehensively annotated for 862 structures, including 117 white matter tracts and several novel cyto- and chemoarchitecturally defined structures, and these annotations were transferred onto the matching MRI dataset. Neocortical delineations were done for sulci, gyri, and modified Brodmann areas to link macroscopic anatomical and microscopic cytoarchitectural parcellations. Correlated neuroimaging and histological structural delineation allowed fine feature identification in MRI data and subsequent structural identification in MRI data from other brains. This interactive online digital atlas is integrated with existing Allen Institute for Brain Science gene expression atlases and is publicly accessible as a resource for the neuroscience community. J. Comp. Neurol. 524:3127–3481, 2016.

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INDEXING TERMS: brain atlas; cerebral cortex; hippocampal formation; thalamus; hypothalamus; amygdala; cerebellum; brainstem; MRI; DWI; cytoarchitecture; parvalbumin; neurofilament protein; RRIDs: AB_10000343; AB_2314904; SCR_014329
The advent and improvement of noninvasive techniques such as magnetic resonance imaging (MRI), functional (f)MRI, and diffusion-weighted imaging (DWI) have vastly enriched our understanding of the structure, connectivity, and localized function of the human brain in health and disease (Glover and Bowtell, 2009; Evans et al., 2012; Amunts et al., 2014). Interpretation of these data relies heavily on anatomical reference atlases for localization of underlying anatomical partitions, which also provides a common framework for communicating within and across allied disciplines (Mazziotta et al., 2001; Toga et al., 2006; Bonnici et al., 2012; Evans et al., 2012; Caspers et al., 2013a; Annese et al., 2014). While neuroimaging data are typically registered to probabilistic reference frameworks (Das et al., 2016) to deal with interindividual variation, they lack the cytoarchitectural resolution of single-brain histological reference atlases (Evans et al., 2012; Caspers et al., 2013a), which is essential for more detailed studies of structural and cellular organization of the brain. There is therefore a strong need to bridge these levels of resolution to understand structure-function relationships in the human brain (Caspers et al., 2013a; Pascual et al., 2015).

A tremendous amount of effort has been dedicated to histology-based parcellation of discrete regions of the human brain, including the frontal, parietal, temporal, occipital, cingulate, and perihinal cortices (Hof et al., 1995a; Van Essen et al., 2001; Vogt et al., 2001; Öngür et al., 2003; Schepervjas et al., 2008; Zilles and Amunts, 2009; Ding et al., 2009; Ding and Van Hoesen, 2010; Goebel et al., 2012; Petrides and Pandya, 2012; Caspers et al., 2013b), and other regions such as the thalamus, amygdala, hippocampus, and brainstem (e.g., De Olmos, 2004; García-Cabezas et al., 2007; Jones, 2007; Morel, 2007; Mai et al., 2008; Ding et al., 2010; Paxinos et al., 2012; Ding and Van Hoesen, 2015). Currently available large-scale histological reference atlases of the human brain vary substantially in their degree of brain coverage, information content, and structural annotation (Table 1), and much of the more recent work is absent in these atlases. The most commonly used cytoarchitecture-based human brain atlas is Brodmann’s cortical map (Brodmann, 1909; Talairach and Tournois, 1988; Šimić and Hof, 2015), particularly for its use in annotating fMRI data, although von Economo’s (von Economo and Koskinas, 1925) and Sarkisov’s (Sarkisov et al., 1955) cortical maps are also still referenced. More recently developed large-scale atlases possess greater anatomical coverage and multimodal information content, but are generally limited by their degree of structural delineation, particularly for neocortical areas that are often referenced only by gyral patterning (Duvernoy, 1999; Fischl et al., 2004; Damasio, 2005; Mai et al., 2008; Naidich et al., 2008; Destrieux et al., 2010; Nowinski and Chua, 2013). To overcome these limitations, a 3-dimensional (3D) model of an adult human brain based on whole-brain serial sectioning, silver staining, and MRI (Amunts et al., 2013) was recently created, and a probabilistic cytoarchitectural atlas (JuBrain; see Caspers et al., 2013a) is also being generated. However, the staining of these specimens is limited, the imaging of the histology data currently lacks cellular resolution, and detailed annotation or parcellation of all brain regions based on cytoarchitecture remains to be performed. Additional efforts have used ultra-high-resolution MRI of ex vivo brains to build intrinsically 3D models of cytoarchitectural boundaries, and quantify the predictive power of macroscopic features for localizing microscopically defined boundaries (Augustinack et al., 2005, 2010, 2012, 2013, 2014; Fischl et al., 2008, 2009; Iglesias et al., 2015). While these latter atlases represent major advances, currently available resources still lack many features of modern atlases available in rodents and nonhuman primates such as multimodality, dynamic user interfaces with scalable resolution and topographic interactivity, and brain-wide anatomic delineation with ordered hierarchical structural ontologies.

We aimed to develop an adult human brain atlas with many of the features of modern digital atlases in model organisms (Lein et al., 2007; Saleem and Logothetis, 2012; Papp et al., 2014). First, the atlas requires whole-brain coverage with neuroimaging (MRI, DWI) and histology using multiple stains in the same brain, allowing brain parcellation based on convergent evidence from cyto- and chemoarchitecture, to reflect functional properties of corresponding brain regions more accurately (Ding et al., 2009; Amunts et al., 2010; Caspers et al., 2013a,b; Pascual et al., 2015). Second, we aimed for true cellular resolution (1 μm/pixel) on histological images to link microscopic features with the macroscopic scales more common in neuroimaging studies. Most critically, we performed comprehensive structural annotation at a very detailed level, based on a hierarchical structural ontology and using multiple forms of neocortical annotations to link gross anatomical (gyral, sulcal) and histology-based parcellation schemes modified from Brodmann. Finally, these data are combined in an interactive, publicly accessible online application with direct linkage to other large-scale human brain gene expression databases (http://human.brain-map.org; Hawrylycz et al., 2012).

MATERIALS AND METHODS

Specimen

The brain used for this reference atlas was from a 34-year-old female donor with no history of neurological
| Coverage            | This atlas | Brodmann (1909) | von Economo and Koskinas (1925) | Talairach and Tournoux (1988) | Duvernoy (1999) | Mai et al. (2008) | Caspers et al. (JuBrain, 2013a)³ |
|---------------------|------------|-----------------|-------------------------------|-----------------------------|----------------|------------------|-------------------------|
| Datasets            | Whole brain| Cerebral cortex | Cerebral cortex                | Cerebrum                    | Cerebrum       | Cerebrum         | 10 brains (mainly cerebral cortex) |
| Data formats        | Nissl      | Nissl           | Based on Brodmann’s map       | Brain slices and MRI (not from the same brain) | Static+electronic version   | Digital          |
| Resolution          | Digital (up to 1 μm/pixel) | Static | Static | Static | Static | Static | Digital |
| Density of annotated plates | 106 coronal plates | Very limited photographs | Limited photographs | 38 coronal plates | 86 coronal plates | 69 coronal plates | Not known |
| Cortical parcellation | Modified Brodmann’s areas | Brodmann’s areas | Von Economo’s areas | Brodmann’s areas | Cortical sulci & gyri only | Cortical sulci & gyri only | Cytoarchitectural areas |
| Labeled fiber tracts | No | No | Large fiber tracts (~117) | Large fiber tracts (~15) | Large fiber tracts (~10) | Major fiber tracts (~40) | Large fiber tracts (~11) |
| Brainstem annotation | Nuclei, subdivisions, and fiber tracts | Not available | Not available | Not annotated | Basically not available² | Basically not available² | Not available |
| Cerebellum annotation | Lobules, zones, deep nuclei, and fiber tracts | Not available | Not available | Not annotated | Not available | Not available | Not available |
| Total annotated structures | ~862 (including nearly all gyri and sulci) | ~50 | ~107 | ~65 | Nearly all gyri and sulci | Nearly all gyri and sulci | ~60 structures available so far |
| Dimension           | 2D         | 2D              | 2D                           | 2D                          | 2D             | 2D               | 3D                      |
| Interactivity       | Highly interactive | No | No | No | No | Somewhat interactive (electronic form) | Interactive |
| Accessibility       | Free to public (no registration needed) | Book | Book | Book | Book | Book | Free |

¹Many human brain MRI atlases generated on basis of gross anatomy were not included.
²Only a small portion of the superior colliculus regions was available.
³BigBrain (Amunts et al., 2013) from this group is a whole brain 3D model based on silver stain with a resolution at 20 μm/pixel but little anatomical annotation was applied to it so far.
diseases or remarkable brain abnormality obtained from the University of Maryland Brain and Tissue Bank, a brain and tissue repository of the NIH NeuroBioBank. All work was performed according to guidelines for the research use of human brain tissue and with approval by the Human Investigation Committees and Institutional Ethics Committees of the University of Maryland, the institution from which the sample was obtained.

General tissue processing

A general workflow for generating this atlas is shown in Figure 1. After the brain was removed from the skull, 4% periodate-lysine-paraformaldehyde (PLP) was injected into the internal carotid and vertebral arteries following a phosphate-buffered saline (PBS) flush. The brain was then suspended and immersed in 4% PLP at 4°C. This preparation appeared to result in a slight elongation of the brain. Following complete fixation (48 hours), the brain was subjected to MRI and DWI (see details below) and stored in PLP at 4°C until further processing. The fixed brain was bisected through the midline. Following agarose embedding, each hemisphere was cut with a flexi-slicer in the anterior to posterior direction, resulting in eight 2-cm-thick slabs. The slabs were cryoprotected in PBS containing 10%, 20%, and 30% sucrose, respectively and then frozen in a dry ice/isopentane bath (between −50°C and −60°C). Finally, the frozen slabs were placed in plastic bags that were vacuumed sealed, labeled, and stored at −80°C until histological sectioning.

Sectioning was performed by Neuroscience Associates (Knoxville, TN). The slabs were individually thawed rapidly in PBS, treated overnight with 20% glycerol and 3% dimethylsulfoxide to prevent freezing artifacts, and rapidly in PBS, treated overnight with 20% glycerol and 3% dimethylsulfoxide. The blocks were then processed with nickel-diaminobenzidine tetrahydrochloride (DAB) and hydrogen peroxide.

Antibody characterization

The antibody against NFP (BioLegend, Cat.# SMI-32, RRID: AB_2314904) is a mouse monoclonal IgG1 recognizing a double band at MW 200,000 and 180,000, which merge into a single neurofilament H line on 2D blots (Sternberger and Sternberger, 1983) (Table 2). The immunostaining of sections through human temporal cortex produced a pattern of NFP labeling that was identical to previous descriptions (Ding et al., 2009). In human and monkey cerebral cortex, the antibody stains a subpopulation of large pyramidal neurons with the labeling largely restricted to dendritic processes and soma (Campbell and Morrison, 1989; Hof et al., 1995a,b; Nimchinsky et al., 1997; Ding et al., 2003, 2009).

The anti-PV antibody is a mouse monoclonal IgG1 (Swant, Cat.# 235, RRID: AB_10000343) is a mouse monoclonal IgG1 recognizing a double band at MW 200,000 and 180,000, which merge into a single neurofilament H line on 2D blots (Sternberger and Sternberger, 1983) (Table 2). The immunostaining of sections through human temporal cortex produced a pattern of NFP labeling that was identical to previous descriptions (Ding et al., 2009). In human and monkey cerebral cortex, the antibody stains a subpopulation of large pyramidal neurons with the labeling largely restricted to dendritic processes and soma (Campbell and Morrison, 1989; Hof et al., 1995a,b; Nimchinsky et al., 1997; Ding et al., 2003, 2009).

The anti-PV antibody is a mouse monoclonal IgG1 (Swant, Cat.# 235, RRID: AB_10000343). This antibody was produced by immunizing mice with PV from carp muscle and hybridizing mouse spleen cells with myeloma cell lines. This antibody specifically stained the 1999Ca-binding “spot” of PV (MW 12,000) from rat cerebellum on 2D immunoblot assays (Celio et al., 1988).
(Table 2). No staining was observed when the antibody was used to stain cortical tissues from PV knockout mice. This antibody labels subsets of nonpyramidal neurons in cerebral cortex of many species including human (Hof et al., 1999; Nimchinsky et al., 1997; Ding and Van Hoesen, 2010, 2015).

**Digitization of all stained sections**

A custom-designed large-format microscopy system was created to allow digital imaging and processing of all histologically stained sections (Nikon, Melville, NY). The system operates by collecting hundreds of images in lengthwise strips, which are montaged to create a
single hemispheric image at 1 \mu m/pixel resolution. A total of 1,356 sections on 3 × 5-inch slides were digitized for this resource, of which a single section (representative dimension: \( \sim 3.2 \times 4.3 \) m) typically took 6–8 hours to complete. Exposure time, white balance, and flat-field correction were set independently for each slide. The Nikon NIS-Elements Advanced Research (AR) microscope imaging software suite (RRID: SCR_014329) was used for acquisition of ND2 format image files that were subsequently converted to TIFF format.

**Digital atlas design and annotation**

For detailed anatomical delineation, 106 Nissl-stained sections were selected out of 679. Sampling intervals varied from 0.4 to 3.4 mm across the full anterior–posterior (A-P) extent of the entire left hemisphere. Sparser sampling (3.4 mm) was selectively applied to the most anterior (prefrontal) and posterior (occipital) cortical levels that primarily contain cortex and a few large subcortical structures. Where smaller subcortical structures are more abundant, a much denser sampling was used (0.4–1.0-mm interval). In total, 862 brain structures were digitally annotated on the 106 whole-hemisphere images using 11,398 polygons.

Anatomical delineations were performed on posterior-sized printouts of Nissl-stained sections and then digitally scanned and registered to the original Nissl images. Structure outlines were converted to digital polygons using Adobe (San Jose, CA) Creative Suite 5, and converted to Scalable Vector Graphics (SVG) format for web utilization. Polygons were linked to the hierarchical structural ontology and color-coded according to the ontology color scheme such that related structures fall into similar color groups. Furthermore, hues were assigned according to the relative cellular density of the structure: the higher the density, the deeper the shade (i.e., addition of black to hue); the lower the density, the deeper the tint (i.e., addition of white to hue).

**Magnetic resonance and diffusion-weighted imaging**

High-resolution structural imaging was performed using special coils designed to optimize signal-to-noise and contrast-to-noise ratios (SNR and CNR, respectively) in fixed specimens by reducing large spacing between the coil elements and the sample. DWI was performed using standard Siemens head coils. Sample packing was performed by vacuum-sealing the brain specimen in a polyethylene storage bag surrounded by PLP to avoid any artifacts caused by the interface between air and tissue. Diffusion-weighted images were collected on a 3 T Tim Trio whole-body scanner (Siemens Medical Solutions, Erlanger, Germany) with a Siemens 32 channel head coil. High-resolution structural images were acquired using a 7 T scanner (Siemens Medical Solutions) with a custom 30-channel receive-array coil designed to image the entire adult brain, utilizing a 36-cm head gradient coil.

For the 7 T scans, custom pulse sequence software was used to measure k-space in “chunks” small enough to be held in the scanner hard disk buffer, and a system was developed to stream each “chunk” of data from the buffer to a multiterabyte RAID array in parallel with it being measured by the scanner. Systems integration and custom software were developed for fast, reliable network and RAID connections and data stream management. Images from each coil channel were reconstructed and combined into a single image using a noise-weighted combination to optimize SNR.

The noise covariance matrix for a coil array is estimated from a noise-only measurement collected in the absence of any RF excitation. This acquisition lasts about 20 seconds and provides enough thermal noise samples to accurately estimate the noise covariance matrix for the 30-channel coil and describes the thermal noise coupling between the individual coil channel images for unaccelerated acquisitions. The final combined image is then computed as a noise-weighted sum of the complex-valued individual coil channel images and is given by

\[
I = \sqrt{\Psi^T \Psi} s
\]

where \( I \) represents the combined image intensity at a given pixel, \( \Psi \) represents the \( N \times N \) noise covariance matrix, and \( s \) represents the \( N \times 1 \) vector of complex-valued image intensities at a given pixel across the \( N \)
coils of the array (Roemer et al., 1990; Wright and Wald, 1997).

For 7 T images, gray and white matter CNR was optimized, to best distinguish these tissue classes as well as discern laminar intracortical architecture. Structural data were acquired using a multiecho flash sequence (TR = 50 ms, $\alpha = 20^\circ, 40^\circ, 60^\circ, 80^\circ$, 6 echoes, TE = 5.49 ms, 12.84 ms, 20.19 ms, 27.60
ms, 35.20 ms, 42.80 ms, at 200-μm isotropic resolution).

Diffusion-weighted data were acquired over two averages using a 3D steady-state free precession (SSFP) sequence (TR = 29.9 ms, α = 60°, TE = 24.96 ms, 900-μm isotropic resolution). Diffusion weighting was applied along 44 directions distributed over the unit sphere (effective b-value = 3,686 s/mm²) (Miller et al., 2012) with eight b = 0 images. The two acquisitions were coregistered using FSL’s FLIRT to correct for B₀ drift and eddy-current distortions (Jenkinson and Smith, 2001) and then averaged before further processing. DWI analysis was done using Diffusion Toolkit (dtk), and Trackvis was used for visualization of tracts (http://trackvis.org/) (Wang et al., 2007). The fiber tracking algorithm is based on the fiber assignment by continuous tracking (FACT) algorithm (Mori et al., 1999). Diffusion-weighted images were rotated to the same orientation as the MRI volume to allow generation of plane-matched MRI and DWI images for the atlas, and the corresponding transformation was applied to the gradient table used to acquire the images. Tracts were created using a 60° angular threshold, masked so tracts are only contained within the approximate brain volume. The primary eigenvectors of the diffusion tensor were overlaid on the fractional anisotropy (FA) map in Freeview (part of the FreeSurfer software package, http://freesurfer.net) to create color FA images. Tractography images were generated in TrackVis with a tract threshold of 20 mm and 90% skip applied, using a Y filter to select all tracts that pass through each coronal plane.

RESULTS

Whole-brain multimodal data generation

To obtain multimodal datasets from the same specimen, ex vivo MRI and DWI scans (at 7 T and 3 T, respectively) of both hemispheres were collected (Fig. 2A,B) prior to histological processing. For anatomic atlasing, the left hemisphere including the connected brainstem and cerebellum (Fig. 2C) was coronally divided into 2-cm slabs, and each slab was serially sectioned at 50 μm (Fig. 2D). Every fourth section (200-μm sampling interval) was stained for Nissl substance (Fig. 2E), and every eighth section was immunostained for NFP (400-μm interval) or PV (400-μm interval) to facilitate accurate delineation of the Nissl-stained sections (Fig. 3A–C). Histological sections were imaged at cellular resolution allowing neuronal soma, dendrites, and axons to be clearly identified (Fig. 2F). A subset of Nissl-stained sections was selected for detailed anatomical delineation with sampling density higher in regions with greater structural complexity. This strategy enabled adequate sampling of small but functionally critical structures such as the suprachiasmatic nucleus.
Figure 4. Detailed delineation of the human hypothalamus. A high sampling density (about 40 plates total, with 20 shown here) covering the entire anterior–posterior (A–T) extent of the hypothalamus was employed to ensure sampling and annotation of even the smallest structures such as the suprachiasmatic nucleus (SCN in A–C). For abbreviations see the hypothalamic part of the ontology in Table 3. Scale bar = 1,940 μm in T (applies to A–T).
in the hypothalamus (Fig. 4) and the area postrema in the medulla.

Creation of a unified structural brain ontology

An essential component of modern interactive digital atlases is a unifying hierarchical structural ontology that provides unique IDs (and colors for representation) for each structure in a parent–child architecture. We created a whole-brain ontology spanning all adult structures (Table 3) and including a developmental axis for transient structures observed during the specification and cytoarchitectural maturation (Miller et al. 2014). The ontology is fundamentally divided into the basic subdivisions of forebrain, midbrain, and hindbrain, further divided into four major branches comprising gray matter, white matter, ventricles, and surface features. For example, daughter structures of “gray matter of forebrain” (Fig. 2G) include the telencephalon, diencephalon, and transient structures of forebrain (e.g., subplate and ventricular zone of the neocortex), while “white matter of forebrain” includes nearly all commissural and long ipsilateral fiber tracts. “Ventricles of forebrain” includes the lateral and third ventricles and related structures, while “surface structures of forebrain” includes important gross landmark features such as cortical gyri and sulci.

For cortical structures, we aimed to accommodate both gyral and sulcal parcellation common to neuroimaging studies as well as cytoarchitectural parcellation based on histology, for which two basic terminologies based on Brodmann (Brodmann, 1909) and von Economo (von Economo and Koskinas, 1925; von Economo, 1927) are in usage. We used Brodmann’s nomenclature as the primary reference because it is more commonly used, with modifications based on modern literature (see below) and the combined whole-brain large-scale cyto- and chemoarchitectural analysis here. Specifically, the following sources were used to modify the Brodmann scheme: for the frontal and cingulate cortex: Hof et al. (1995a), Vogt et al. (1995), Vogt et al. (2001), Öngür et al. (2003), Petrides and Pandya (2012), and Vogt and Palomero-Gallagher (2012); for parietal, temporal, and occipital cortices (mostly changed to Brodmann’s terminology where other nomenclature was used): Caspers et al. (2013b), Ding et al. (2009), Ding and Van Hoesen (2010), Schepersjans et al. (2008), Van Essen et al. (2001), Zilles and Amunts (2009), and Goebel et al. (2012). The terminology for the hippocampal formation is derived from Ding and Van Hoesen (2015) and Ding (2013, 2015). For a few cortical areas that Brodmann (1909) did not parcellate in detail (Simić and Hof, 2015), such as posterior parahippocampal areas (areas TH, TL, and TF), we adopted a modified nomenclature from von Economo and Koskinas (1925; see Ding and Van Hoesen, 2010). Another example of modification of Brodmann’s areas is the orbitofrontal cortex, where Brodmann’s large area 11 was replaced with smaller areas 14, 11, and 13 according to a few modern anatomical studies in human (Hof et al., 1995a; Öngür et al., 2003) and our own investigation of Nissl preparations and PV- and NFP-immunostained sections. In addition, some of Brodmann’s areas were further subdivided according to recent literature and the analysis here. For instance, Brodmann’s areas 22 and 21 (roughly corresponding to von Economo’s areas TA and TEd) were subdivided into rostral, intermediate, and caudal parts based on different staining intensity in PV-stained sections (Ding et al., 2009). Finally, for the insular cortex that was not numbered by Brodmann in human (1909; see Simić and Hof, 2015), three major subdivisions were delineated and these included agranular, dysgranular, and granular insula (e.g., Bauernfeind et al., 2013; Morel et al., 2013), with the latter two further divided into rostral and caudal parts.

Structures from the ontology were delineated as polygons on each Nissl digital image (Fig. 2H), and these structures include both gyral (Fig. 211) and modified Brodmann areas (Fig. 212) of the neocortex. Together, this comprehensive ontology covers all brain regions and can be used interactively to browse and search delineated structure polygons. It also provides enhanced interlinking capabilities among a broad range of datasets including adult (Hawrylycz et al., 2012) and developing (Miller et al., 2014) human brain transcriptional atlases included in the Allen Brain Atlas (www.brain-map.org).

Delineation of cortical and subcortical gray matter

Anatomical delineation for the 106 selected plates (Fig. 2H) was based on a combined analysis of cyto- (Nissl stain) and chemoarchitecture (NFP and PV immunohistochemistry). For example, the boundaries between areas 29 and the neighboring suprasplenial subiculum (SuS) and caudal presubiculum (PrSc; also known as the postsubiculum [PoS]) were confidently identified based on staining features revealed in Nissl- (Fig. 5A), and adjacent PV- and NFP- (Fig. 5B and inset) immunostained sections. Dark NFP and PV immunoreactivity highlights SuS and PrSc, respectively, and these complementary and corroborating data allowed a consensus digital annotation of these regions (Fig. 5C). Similarly, in the ventral temporal neocortex, the border between areas 36 and 20 can be more accurately defined with PV immunostaining than Nissl alone, as area 20 (20i) displays significantly stronger PV immunoreactivity than area 36 (Fig. 5D,E).
Figure 5. Defining cortical boundaries with a combined analysis of Nissl-, NFP-, and PV-stained sections. A, B, and inset in B: Boundary determining of the indusium griseum (IG), supracallosal subiculum (SuS), retrosplenial areas 29 (A29) and 30 (A30), and caudal presubiculum (PrSc; or postsubiculum [PoS]). C: Color-coded map of the region shown in A and B. cc, corpus callosum. PV and NFP immunostaining patterns help delineate neocortical borders and white matter tracts. D, E: Differences in PV immunolabeling intensity helps define the boundaries between area 36 and area 20 (20i). Scale bar = 1,106 μm in C (applies to A-C) and E (applies to D, E).
Figure 6. Defining boundaries of cortical and subcortical structures with NFP- (A–F) and PV- (G) stained sections. A–C: NFP staining patterns in primary motor cortex (M1C), primary somatosensory cortex (S1C), and the rostro dorsal portion of area 40 (A40rd). The locations of these three cortical areas were marked with *, **, and *** respectively in Figure 8A. Arabic numbers specify cortical layers. D: NFP staining pattern in the thalamus (Thal) defines Pf, CM, and adjoining structures. CM, centromedian nucleus; MD, mediadorsal nucleus; Pf, parafascicular nucleus. VPI, ventral posterior inferior nucleus; VPM, ventral posterior medial nucleus; VPMpc, parvocellular part of VPM. E, F: NFP is observed in select white matter tracts in the brainstem including the facial (r7 in E) and trochlear (r4 in F) nerve roots. 6N, abducens nucleus; r7, facial nerve root; x4, decussation of trochlear nerve roots (r4 in F). G: PV is selectively expressed in the commissure of the inferior colliculus (cmic). Scale bar = 777 μm in C (applies to A–C), D, and E; 277 μm in F; 88 μm in G.
NFP immunoreactivity was in many cases more informative than Nissl stain for delineation of cortical regions based on the selective labeling of pyramidal neuron populations in different layers. For example, many large pyramidal neurons in layer 5 of the primary motor cortex (M1C; Fig. 6A) are NFP-immunoreactive, while only a small number of medium-sized neurons are observed in that layer of the primary somatosensory cortex (S1C; Fig. 6B). In contrast, the inferior parietal area (rostrodorsal area 40 [area 40rd], located posterior

Figure 7. Defining white matter fiber tracts and subcortical structures with combined analysis of NFP and PV stains. A–C: Combined analysis of NFP immunoreactivity (A) and Nissl staining (B) in the medulla leading to anatomical parcellation (C). NFP clearly delineates specific cranial nuclei (e.g., 10N, 12N) and fiber tracts (e.g., r12). D,E: PV-immunoreactive axons in the external part of sagittal stratum/optic radiation ("or" in D and inset) compared with the internal part of the sagittal stratum (ssti) and tapetum of the corpus callosum (tap) that do not show PV immunoreactivity. Inset: High-magnification view of PV-immunoreactive axons in the optic radiation (*). 10N, dorsal motor nucleus of vagus nerve; 12N, hypoglossal nucleus; iLV, inferior horn of the lateral ventricle; IO, inferior olive; r12 and r10, hypoglossal and vagus nerve roots; Scale bar = 777 µm in A (applies to A,B); 1,554 µm in D.
to S1C; Fig. 6C), has a narrower band of superficial layer labeling and a stronger bilaminar pattern. The combined analysis of Nissl staining and NFP or PV immunolabeling was also useful in defining many subcortical regions and subdivisions such as ventroposterior inferior (VPI), parafascicular (Pf), and centromedian (CM) nuclei in the thalamus (Thal; Fig. 6D) and cranial motor nuclei of the brainstem (Figs. 6E, 7A–C).

Localisation and delineation of white matter tracts
We also aimed for a comprehensive delineation of white matter tracts and cranial nerves (117 total), aided by NFP and PV fiber immunostaining. Motor roots of the cranial nuclei in the brainstem are clearly delineated by NFP staining (Figs. 6E, G, 7A). PV immunoreactivity shows similar discernment of a variety of fiber tracts and trajectories, such as the commissure of the inferior colliculus (Fig. 6F) and the optic radiation (Fig. 7D,E). A representative fully annotated atlas plate is shown in Figure 8A, with complete cyto- and chemoarchitecture-based parcellation and colorization superimposed on the original Nissl image (Fig. 8C). To relate macroscopic (landmarks) and microscopic (histology) cortical anatomy, parallel plates were created with parcellation by gyri and sulci (Fig. 8B) or modified Brodmann areas (Fig. 8A). The denser sampling of subcortical regions allowed comprehensive detailed annotation of fine nuclear architecture for all major regions, as illustrated for the hypothalamus (Fig. 4) and the amygdala (Fig. 9).

Identification of novel brain subregions
In addition to confirming previously identified structures, the combination of high image resolution and dense (200-μm-interval) Nissl sampling made it possible to reveal or clarify a number of complex or smaller brain structures, while the linkage to the Allen Human Brain Atlas (Hawrylycz et al., 2012) allowed corroboration of these structures with other gene expression data. One example is in the mediodorsal nucleus (MD) of the thalamus, where we observed a group of densely packed larger cells between the paraventricular nucleus (PaV) and the main portion of the MD, which we named the anteromedial subdivision of the MD (MDam in Fig. 10A). In situ hybridization data of both acetylcholinesterase (ACHE) and neurotensin (NTS) supports this partition, as they are selectively enriched in this region compared with the main part of the MD (Fig. 10B and inset). Similarly, we identified a novel subdivision of the basomedial nucleus (BM) of the amygdala. This

Figure 8. Alternate schemes for cortical parcellation. Modified Brodmann’s areas (A) or sulci and gyri (B) were annotated on the same Nissl-stained plate (C) to show micro- and macrostructural relationships. Examples of how cortical areas were delineated are given in Figures 5 and 6. The markers (*, **, *** ) and (#) in A indicate the locations of pictures in Figure 6A–C and Figure 5D,E, respectively. For abbreviations see the ontology in Table 3. Inset is a schematic representation of the whole hemisphere based on MRI, with the red vertical lines in A and B indicating the location of the section plate. Both modified Brodmann’s areas and gyral/sulcal mapping of the cerebral cortex are available online at www.branspan.org. Scale bar = 3,108 μm in A–C.
Figure 9. Detailed parcellation of the human amygdalar complex. Shown are ten of the 18 annotated plates covering the A-P extent (A–J) of the amygdala. For abbreviations see the amygdalar portion of the ontology in Table 3. Scale bar = 3,102 μm in J (applies to A–J).
Figure 10. Novel subdivisions of the mediodorsal nucleus (MD) of the thalamus and basomedial nucleus (BM) of the amygdala. A: Nissl staining reveals a group of larger cells (termed MDam, labeled with * in high magnification image and overview atlas plate (inset)) located between the paraventricular nucleus (PaV) and anterior mediodorsal nucleus (MDm) of the thalamus distinct from neighboring regions. B: Distinct molecular specificity of MDam is demonstrated by ISH for ACHE and NTS (inset in B). C,D: Novel subdivision of amygdalar basomedial nucleus differentiated by smaller and relatively lightly Nissl-stained cells (termed BMm, labeled with * in high magnification image and overview atlas plate (inset) in C) and selective enrichment for the GABA receptor subunit E (GABRE, in D) compared with neighboring dorsal and ventral regions (BMD and BMV) and posterior cortical nucleus (CoP). Scale bar = 1,109 μm in B (applies to A,B); 1,550 μm in D (applies to C,D).
subdivision is located medial to the dorsal and ventral subdivisions of the BM (BMD and BMV) and was termed BMm (medial subdivision of BM; Fig. 10C and inset). The BMm displays enriched cellular expression of the \( \gamma \)-aminobutyric acid (GABA) receptor subunit E (\( \text{GABRE} \)) compared with the neighboring BMD and BMV (Fig. 10D). The homologs of MDam and BMm in other species have not been reported.

Another new area was identified running along the side of lateral olfactory stria, situated medially to the piriform cortex (Pir) and laterally to the substantia innominata (SI). This was termed the lateral olfactory area (LOA) and was found to have distinct histological features from the neighboring Pir and SI (Fig. 11). Compared with the Pir, the LOA does not have a dark, densely packed layer 2 on Nissl stain and has much stronger NFP immunoreactivity. In Nissl-stained materials, the SI contains many cellular patches of differing sizes, packing densities, and staining intensities, with cells of contrasting shapes and sizes, compared with...
Figure 12. Location and topographic relationship of area prostriata (APro). APro (labeled as Pro) is adjoined by the retrosplenial cortex (areas 29 and 30, not shown), postsubiculum (PoS in A), posterior cingulate cortex (area 23 in B–D) anterodorsally, and dorsal secondary visual cortex (V2d in D–G) posterodorsally. Anteroventrally, APro is adjoined by the ventral secondary visual cortex (V2 in A–D). Posteroventrally and posteriorly, APro is adjoined by the anteroventral part of the primary visual cortex (V1v in E–H). Scale bar = 4,420 μm in H (applies to A–H).
the LOA (Fig. 11A). In sections immunostained for NFP, only the largest neurons are labeled (Fig. 11B). The SI does not display laminar organization, while the LOA has a clear but discontinuous layer 2 and one deep layer. In contrast, the Pir has a dark and continuous layer 2 and a less darkly stained layer 3.

Two other structures described previously only in non-human primates were identified as well, such as area prostriata (APro) and the basal interstitial nucleus of the cerebellum (BLCb). APro is a region located at the junction of the retrosplenial, post- and parasubiculum, posterior cingulate, and anterior-dorsal primary visual cortices. It has been described in detail in macaque monkey (Morecraft et al., 2000; Ding et al., 2003) and is important for fast procession of peripheral vision (Yu et al., 2012). Although its existence in the human brain was briefly described, its exact location and extent has not been reported in detail so far. Our mapping indicates that APro is much larger in human (Fig. 12) than in macaque monkey (Ding et al., 2003). The BLCb in the human brain is located deep to the medial interpositus nucleus (InPM; globose nucleus) of the cerebellum and consists of scattered large NFP-immunoractive neurons (Fig. 13).

Identifying anatomical landmarks in MRI data

Transposing the Nissl-based anatomical delineations into full 3D annotations registered to the accompanying MRI volume is challenging due to the incomplete and nonuniform sampling of those annotations. However, individual Nissl plates can be matched to corresponding planes of the MRI data to allow the identification of features of specific structures that can then be mapped onto MRI data from other brains without accompanying architecture-based delineations. The utility of this approach can be demonstrated in the case of the medial geniculate nucleus (MG) and the dorsal lateral geniculate nucleus (DLG). A comparison of the architecture-based atlas (Fig. 14A) and the corresponding MRI plate (Fig. 14B) from the same brain shows that the MG has high and the DLG low signal intensity. Combining these features with basic spatial topography, the MG and DLG in the MRI scans from other brains from the Allen Human Brain Atlas (Hawrylycz et al., 2012) are clearly discerned (Fig. 14C,D). The MG is so similar in signal intensity to the adjoining white matter (consistently high signal intensity in T1-weighted images) that it would probably be misidentified as white matter if the extracted feature (i.e., high signal intensity) was not used. With the topography of the histology-based parcellation as a guide, many fine structures can be similarly identified in MRI data that would otherwise be difficult to identify and discriminate, thus extending the value of this single brain atlas to the interpretation of neuroimaging data (Fig. 15).

Whole-brain histology-based atlas with corresponding MRI and DWI

The complete set of histology-based atlas plates is presented in Figures 16 and 17. These include a plate locator (Fig. 16) marking the A-P sampling locations of all 106 annotated atlas plates and selected corresponding Nissl-
stained and adjacent NFP and PV immunohistological plates (Fig. 17). To translate the atlas structural delineations onto the MRI dataset, a set of 76 coronal MRI slices at 2-mm intervals (Fig. 18) from the same hemisphere was selected and annotated (Fig. 19, left column). Macroscopic landmarks such as cortical sulci and gyri were used as guides to match histological and MRI planes of section, and local topography was used (e.g. see Figs. 14, 15) to label identifiable structures including all neocortical areas and major subcortical regions.

Some well-known white matter tracts such as the optic radiation (“or” in Fig. 19, levels 42–69) and auditory radiation (“ar”) are clearly visible in the 7 T MRI images and can be clearly followed for a long distance due to their darker appearance than the surrounding white matter. Interestingly, a corresponding part of the somatosensory radiation (named here the “sr”) is also clearly visible (Fig. 19, levels 38–46). The “sr” is normally treated as part of the superior radiation in the literature and mainly originates from the ventroposterior lateral nucleus of the
thalamus and targets the primary somatosensory cortex. In this 7 T MRI dataset, like the “or” and “ar,” the “sr” is observed to stand out from surrounding white matter and thus deserves an independent term (i.e., somatosensory radiation) as do optic and auditory radiations.

Finally, color-coded orientation maps and tractography maps of both hemispheres from the same brain are also available and are presented in Figure 19 (right column). By comparison with the accompanying MRI plates, some white matter fiber tracts can be identified. For example, at level 40 of Figure 19, the callosal and cingulate bundles, superior longitudinal fasciculus (sif-r, sif-l, and sif-l), and somatosensory radiation can be easily localized with the guide of the annotated MRI atlas.

For convenience Figures 16-19 are presented, together with Table 3, after the literature list at the end of the paper.

**DISCUSSION**

Brain reference atlases are essential resources for neuroscience research, serving to identify and annotate the complex anatomical architecture of the brain and allow communication across laboratories and various research disciplines attempting to link structure to function (Fischl et al., 1999; Toga et al., 2006; Amunts et al., 2007; Evans et al., 2012). Ideally, modern digital atlases should comprise 3D reference frameworks with comprehensive anatomical coverage and cellular resolution cyto- and chemoarchitectural histology-based structural annotation using hierarchical ontologies, and correlated histological and neuroimaging data (Toga et al., 2006; Destrieux et al., 2010; Evans et al., 2012; Caspers et al., 2013a). All currently available human brain reference atlases lack some of these features.
Parcellation of the human neocortex presents a particular challenge, as several different schemes based on cortical gyri and sulci or histological delineation are in common usage (Brodmann, 1909; Talairach and Touroux, 1988; Fischl et al., 2004; Duvernoy, 1999; Damasio, 2005; Mai et al., 2008; Destrieux et al., 2010; Petrides, 2012), and the relationship between cortical geometry and architectonic identity is variable across the cortex (Fischl et al., 2008). To serve both communities, we chose to perform multiple annotations of the same dataset. The first is based on macroscopic annotation of gyri and sulci, while the second is based on microscopic analysis of combined cyto- and chemoarchitectural data to create a modified Brodmann parcellation. This unique human dataset of interleaved Nissl staining, and NFP and PV immunolabeling in a whole hemisphere, allowed a complete parcellation based on variations in overall cell density, NFP immunolabeling of subsets of long-range excitatory projection neurons, and PV-expressing neurons and neuropil. In many cases this parcellation agrees with other techniques such as receptor autoradiography and Nissl-based gray-level indices (Zilles and Amunts, 2009; Amunts et al., 2010; Vogt et al., 2013). For example, the inferior parietal lobule has been consistently divided into three basic regions based on cellular and receptor architecture (Caspers et al., 2013b), and our analysis of cyto- and chemoarchitecture corroborates this tripartite delineation (albeit with a different nomenclature). In many other cases these data allowed a detailed parcellation of regions that had not yet been examined in detail by others, such as the area prostriata and other structures described above. In principle, this dataset could be reannotated by other researchers to provide alternate interpretations. Finally, this dataset could be aligned to new functional parcellations based on neuroimaging data, such as a recent analysis from the Human Brainnetome Atlas (Fan et al., 2016) and the Human Connectome Project (www.humanconnectome.org; Glasser et al., 2016), opening up new possibilities for linking cytoarchitecture and function at microscopic and macroscopic scales.

There is a fundamental schism between probabilistic reference atlases used in neuroimaging (Hammers et al., 2003; Ahsan et al., 2007; Schepersjans et al., 2008; Shattuck et al., 2008; Diedrichsen et al., 2009; Kuklisova-Murgasova et al., 2011), based on thousands of individuals, and detailed histological reference atlases based on exhaustive analysis and annotation of single representative brain specimens (Brodman, 1909; von Economo and Koskinas, 1925; Sarkisov et al., 1955). It is not currently possible to analyze large numbers of whole brains histologically and thus build a probabilistic histological atlas, although strong efforts are under way to move in the direction of generating probabilistic histological reference atlases using standard histological (JuBrain; Caspers et al., 2013a) as well as novel imaging techniques (Magnain et al., 2014, 2015; Wang et al., 2014; Zilles et al., 2016). Furthermore, human brains exhibit a remarkable amount of interindividual variability, particularly in the gyri and sulci of the cerebral cortex (Mazziotta et al., 2001; Uylings et al., 2005; Toga et al., 2006; Amunts et al., 2007; Ding and Van Hoesen, 2010; Zilles and Amunts, 2010, 2013). For instance, one brain may have area 35 located in the medial bank of a deep collateral sulcus (CoS), while another may have its area 35 in the lateral bank of a shallow CoS, or even the crown of the anterior fusiform gyrus (Ding and Van Hoesen, 2010). Thus it is not realistically meaningful to map histological annotations from a single specimen directly into a probabilistic reference space, even with advances in techniques for deformable registration. On the other hand, the current generation of both MRI and DWI data in the same specimen as the histological data allows the direct correlation of cytoarchitectural features with MRI features or landmarks. As we demonstrate, this dataset may thus allow feature extraction that can be applied to other brains to identify fine anatomical structures not otherwise identifiable, especially when higher resolution imaging techniques such as 9.4-Tesla MRI, optical coherence tomography, and polarized light microscopy become available (Fatterpekar et al., 2002; Magnain et al., 2015; Zilles et al., 2016).

In summary, we have created a cellular resolution, comprehensively annotated atlas for an entire adult human brain hemisphere (Fig. 17) based on a combined...
analysis of cyto- and chemoarchitectures and modern literature. This combination of anatomic completeness, multimodal histological cellular-resolution imaging, modified Brodmann’s areas delineations in neocortex, neuroimaging (Fig. 19), and intuitive digital interactivity provides an advance over other current large-scale human brain atlases. This versatile and publicly accessible resource gives a range of users a means to learn, teach, and investigate human brain structure and function, including the diagnosis and treatment of brain disease.

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CONFLICT OF INTEREST

B.F. has a financial interest in CorticoMetrics, a company whose medical pursuits focus on brain imaging and measurement technologies. B.F.’s interests were reviewed and are managed by Massachusetts General Hospital and Partners HealthCare in accordance with their conflict of interest policies. The authors declare no competing financial interests.

ROLE OF AUTHORS

All authors had full access to all the data in the study and take full responsibility for the integrity of the data and the accuracy of the data analysis. ESL, S-LD, JRR, and BACF contributed significantly to the atlas design; S-LD generated the anatomic ontology, analyzed the cyto- and chemoarchitectural and MRI data, and delineated anatomical boundaries; JRR, BACF, PL, and BM performed the cartography and quality control; SMS managed the project, and tissue sectioning and staining via NeuroScience Associates; S-LD, SMS, and JRR quality-controlled the stained sections; AB and ND contributed to methods development; TB, AS, LT, AVDK, AV, MW, LZ, and BF contributed to MR and DWI imaging; AG-B and RAD linked this atlas to human brain gene expression datasets; RAD, ES, ZLR, and HRZ contributed to the processing of the human specimen; SC, JN, DS, and MR provided technical support; LN, TAD, and CD managed the creation of the data pipeline, visualization, and mining tools; LN, AS, and CD conducted informatics data processing and online database development; JGH managed the annotation team; ESL, MJH, JGH, AB, CD, PW, JAK, NS, JWP, PRH, CK, and ARJ contributed to the overall project design; ESL and MJH conceived the project, and the manuscript was written by S-LD and ESL with input from BF, PRH, JGH, MJH, and JRR.

LITERATURE CITED

Ahsan RL, Allom R, Gousias IS, Habib H, Turkheimer FE, Free S, Lemieux L, Myers R, Duncan JS, Brooks DJ, Koepp MJ, Hammers A. 2007. Volumes, spatial extents and a probabilistic atlas of the human basal ganglia and thalamus. Neuroimage 38:261-270.

Amunts K, Schleicher A, Zilles K. 2007. Cytoarchitecture of the cerebral cortex: more than localization. Neuroimage 37:1061–1065; discussion 1066–1068.

Amunts K, Lenzen M, Friederici AD, Schleicher A, Morosan P, Palomo-Gallagher N, Zilles K. 2010. Broca’s region: novel organizational principles and multiple receptor mapping. PLoS Biol 8:9.

Amunts K, Lepage C, Borgeat L, Mohlberg H, Dickscheid T, Rousseau ME, Bludau S, Bazin PL, Lewis LB, Oros-Peusquens AM, Shah NJ, Lippert T, Zilles K, Evans AC. 2013. BigBrain: an ultra-high-resolution 3D human brain model. Science 340:1472–1475.

Amunts K, Hawrylycz MJ, Van Essen DC, Van Horn JD, Harel N, Poline JB, De Martino F, Bjaalie JG, Dehaene-Lambertz G, Dehaene S, Valdes-Sosa P, Thrion B, Zilles K, Hill SL, Abrams MB, Tass PA, Vanduffel W, Evans AC, Eickhoff SB. 2014. Interoperable atlases of the human brain. Neuroimage 99:525–532.

Annese J, Schenker-Ahmed NM, Bartsch H, Maechler P, Sheh C, Thomas N, Kayano J, Ghatan A, Bresler N, Frosch MP, Klapring R, Corkin S. 2014. Postmortem examination of patient H.M.’s brain based on histological sectioning and digital 3D reconstruction. Nat Commun 5:3122.

Augustinack JC, van der Kouwe AJ, Blackwell ML, Salat DH, Wiggins CJ, Frosch MP, Wiggins GC, Potthast A, Wald LL, Fischl BR. 2005. Detection of entorhinal layer II using 7 Tesla magnetic resonance imaging. Ann Neurol 57:489–494.

Augustinack JC, Helmer K, Huber KE, Kakunoori S, Zollei L, Fischl B. 2010. Direct visualization of the perforant pathway in the human brain with ex vivo diffusion tensor imaging, Front Hum Neurosci 4:42.

Augustinack JC, Huber KE, Postelnicu GM, Kakunoori S, Wang R, van der Kouwe AJ, Wald LL, Stein TD, Frosch MP, Fischl B. 2012. Entorhinal verruca geometry is coincident and correlates with Alzheimer’s lesions: a combined neuropathology and high-resolution ex vivo MRI analysis. Acta Neuropathol 123:85–96.

Augustinack JC, Huber KE, Stevens AA, Roy M, Frosch MP, van der Kouwe AJ, Wald LL, Van Leemput K, McKee AC, Fischl B. 2013. Predicting the location of human perirhinal cortex, Brodmann’s area 35, from MRI. Neuroimage 64:32–42.
Augustinack JC, Magnain C, Reuter M, van der Kouwe AJ, Boas D, Fischl B. 2014. MRI parcellation of ex vivo medi-
tal temporal lobe. NeuroImage 93:252–259.

Bauernfeind AL, de Sousa AA, Avasthi T, Dobson SD, Raghanti MA, Lewandoski AH, Zilles K, Semendeferi K, Allman JM, Craig AD, Hol FR, Sherwood CC. 2013. A volumetric
comparison of the insular cortex and its subregions in
primates. J Hum Evol 64:263–279.

Bonnicci HM, Chadwick MJ, Kamaran D, Hassabis D, Weiskopf
N, Maguire EA. 2012. Multi-voxel pattern analysis in
human hippocampal subfields. Front Human Neurosci 6:290.

Brodmann K. 1909. Localisation in the cerebral cortex (Trans-
lated and edited by L. J. Garey, 1994). London: Smith-
Gordon.

Campbell MJ, Morrison JH. 1989. Monoclonal antibody to neu-
rofilament protein (SMI-32) labels a subpopulation of
pyramidal neurons in the human and monkey neocortex. J Comp Neurol 282:191–203.

Caspers S, Eickhoff SB, Zilles K, Amunts K. 2013a. Micro-
structural grey matter parcellation and its relevance for
connectome analyses. NeuroImage 80:18–26.

Caspers S, Schleicher A, Bacha-Trams M, Palermo-Gallagher
N, Amunts K, Zilles K. 2013b. Organization of the human inferior
parietal lobule based on receptor architectonics. Cereb Cortex 23:615–628.

Cepi MR, Baier W, Schärer L, de Viragh PA, Gerday C. 1988.
Monoclonal antibodies directed against the calcium binding
protein parvalbumin. Cell Calcium 9:81–86.

Damasio H. 2005. Human Brain Anatomy in Computerized
Images (2nd Edition). New York: Oxford University Press.

Das S, Glatard T, MacIntyre LC, Madjar C, Rogers C, Rousseau ME, Rioux P, MacFarlane D, Mohades Z,
Gnanasekaran R, Makowski C, Kostopoulos P, Adalat R,
Khalili-Mahani N, Niso G, Moreau JT, Evans AC. 2016. The
MNI data-sharing and processing ecosystem. Neuro-
Image 124:1188–1195.

De Olmos JS. 2004. Amygdala. In: Paxinos G, Mai JK, editors. The human nervous system (second edition). San Diego:
Academic Press, pp. 739–868.

Destrieux C, Fischl B, Dale A, Halgren E. 2010. Automatic par-
cellular of human cortical gyri and sulci using standard
anatomical nomenclature. NeuroImage 53:1–15.

Diedrichsen J, Balsters JH, Flavell J, Cussans E, Ramnani N,
Gregor BW, Haradon Z, Haynor DR, Hohmann JG,
Chong J, Dalley RA, Daly BD, Dang C, Datta S, Dee N,
Horvath S, Howard RE, Jeromin A, Jochim JM, Kinnunen
M, Lau C, Lazarz ET, Lee C, Lemon TA, Li L, Li Y, Morris
Malcolm Jenner, 2007. The human brain: surface, blood supply, and
three-dimensional anatomy, 2nd ed. New York: Springer.

Evans AC, Janke AL, Collins DL, Baillet S. 2012. Brain tem-
plates and atlases. NeuroImage 62:911–922.

Fan L, Li H, Zhuo J, Zhang Y, Wang J, Chen L, Yang Z, Chu C,
Xie S, Laird AR, Fox PT, Eickhoff SB, Yu C, Jiang T. 2016. The Human Brainnetome Atlas: A new brain atlas based
on connectional architecture. Cereb Cortex 26:3508–
3526.

Fatterpekar GM, Naidich TP, Delman BN, Aguinaldo JG,
Gultekin SH, Sherwood CC, Hof PR, Drayer BP, Fayad
ZA. 2002. Cytoarchitecture of the human cerebral cortex:
MR microscopy of excised specimens at 9.4 Tesla. AJNR Am J neuroradiol 23:1313–1321.

Fischl B, Sereno MI, Tootell RB, Dale AM. 1999. High-resolution intersubject averaging and a coordinate system for
the cortical surface. Hum Brain Mapp 8: 272–284.

Fischl B, van der Kouwe A, Destrieux C, Halgren E, Segonne
F, Salat DH, Buse A, Seidman LJ, Goldstein J, Kennedy D,
Caviness V, Makris N, Rose B, Dale AM. 2004. Automat-
cally parcellating the human cerebral cortex. Cereb Cortex 14:11–22.

Fischl B, Rajendran N, Buse A, Augustinack J, Hinds O, Yeo
BT, Mohrberg H, Amunts K, Zilles K. 2008. Cortical fold-
ing patterns and predicting cytoarchitecture. Cereb Cortex 18:1973–1980.

Garcia-Cabezas MA, Rico B, Sánchez-González MA, Cavada C.
2007. Distribution of the dopamine innervation in the
macaque and human thalamus. Neuroimage 34:965–
984.

Glasser MF, Coalson TS, Robinson EC, Hacker CD, Harwell J,
Yacoub E, Ugurbil K, Andersson J, Beckmann CF, Jenkinson M, Smith SM, Van Essen DC. 2016. A multi-
modal parcellation of the human cerebral cortex. Nature
536:171–178.

Glover P, Bowtell R. 2009. Medical imaging: MRI rides the
wave. Nature 457:971–972.

Goebel R, Muckli L, Kim D-S. 2012. Visual system.In: Mai JK,
Paxinos G, editors. The human nervous system, 3rd ed.
New York: Elsevier. p 1301–1327.

Hammers A, Allom R, Koepp MJ, Free SL, Myers R, Lemieux
L, Mitchell TN, Brooks DJ, Duncan JS. 2003. Three-
dimensional maximum probability atlas of the human brain, with particular reference to the temporal lobe.
Hum Brain Mapp 19:224–247.

Hawrylycz MJ, Lein ES, Guillozot-Bongaarts AL, Shen EH, Ng L,
Miller JA, van der Lajegaat LN, Smith KA, Ebbert A, Riley
ZL, Abajian C, Beckmann CF, Bernard A, Bertagnolli D,
Boe AF, Cartagena PM, Chakravarty MM, Chapin M,
Chong J, Dalley RA, Daly BD, Dang C, Datta S, Dee N,
Dolbeare TA, Faber V, Feng D, Fowler DR, Goldy J,
Gregor BW, Haradon Z, Haynor DR, Hohmann JG,
Hovarth S, Howard RE, Jeromin A, Jochim JM, Kinnunen
M, Lau C, Lazarz ET, Lee C, Lemon TA, Li L, Li Y, Morris
Ja, Overly CC, Parker PD, Parry SE, Reding M, Royall JJ,
Schulkin J, Sequeira PA, Slaughterbeck CR, Smith SC,
Sodt AJ, Sunkin SM, Swanson BE, Vawter MP, Williams D, Wohnoutka P, Zielke HR, Geschwind DH, Hof PR, Smith SM, Koch C, Grant SG, Jones AR. 2012. An anatomically comprehensive atlas of the adult human brain transcriptome. Nature 489:391–399.

Hof PR, Mufson EJ, Morrison JH. 1993a. Human orbitofrontal cortex: cytoarchitecture and quantitative immunohistochemical parcellation. J Comp Neurol 359:48–68.

Hof PR, Nimchinsky EA, Morrison JH. 1995b. Neurochemical phenotype of corticocortical connections in the macaque monkey: quantitative analysis of a subset of neurofilament protein-immunoreactive projection neurons in frontal, parietal, temporal, and cingulate cortices. J Comp Neurol 362:109–133.

Hof PR, Glezer II, Condé F, Flagg RA, Rubin MB, Nimchinsky EA, Vogt Weisenhorn DM. 1999. Cellular distribution of the calcium-binding proteins parvalbumin, calbindin, and calretinin in the neocortex of mammals: phylogenetic and developmental patterns. J Chem Neuroanat 16:77–116.

Iglesias JE, Augustinack JC, Nguyén K, Player CM, Player A, Wright M, Roy N, Frosch MP, McKee AC, Wald LL, Fischl B, Van Leemput K. 2015. A computational atlas of the hippocampal formation using ex vivo, ultra-high-resolution MRI: application to adaptive segmentation of in vivo MRI. NeuroImage 115:117–137.

Jenkinson M, Smith S. 2001. A global optimisation method for robust affine registration of brain images. Med Image Anal 5:143–156.

Jones EG. 2007. The thalamus. Cambridge: Cambridge University Press.

Kuklisova-Murgasova M, Aljabar P, Srivinasan L, Counsell SJ, Morecraft RJ, Rockland KS, Van Hoesen GW. 2000. Localization of area prostriata and its projection to the cingulate cortex. J Comp Neurol 384:597–620.

Lein ES, Hawrylycz MJ, Ao N, Ayres M, Bengsinger A, Bernard A, Boe AF, Boguski MS, Brockway KS, Byrnes EJ, Chen L, Chen L, Chen TM, Chin MC, Chong J, Crook BE, Czaplinska A, Dang CN, Datta S, Dee N, Desaki AL, Desta T, Diep E, Dolbeare TA, Donelan MJ, Dung HW, Dougherty JG, Duncan BJ, Ebbert AJ, Eichele G, Estin LK, Faber C, Facer BA, Fielde R, Fischer SR, Fliss TP, Freesly C, Gates SN, Glattfelder KJ, Halverson KR, Hart MR, Hohmann JG, Howell MP, Jeung DP, Johnson RA, Karr PT, Kawal R, Kidney JM, Knapik RH, Kuan CL, Lake JH, Laramee AR, Larsen KD, Lau C, Lemon TA, Liang AJ, Liu Y, Luong LT, Michaels J, Morgan JJ, Morgan RJ, Mortrud MT, Mosquera NF, Ng LL, Ng R, Orta GJ, Overy CC, Pak TH, Parry SE, Pathak SD, Pearson OC, Puchalski RB, Riley ZL, Rockett HR, Rowland SA, Royall J, Ruiz MJ, Sarno NR, Schaffnit K, Shapovalova NV, Sivisay T, Slaughterbeck CR, Smith SC, Smith KA, Sodt AJ, Sopka LA, Stadler E, Stumpp KR, Sunkin SM, Suram M, Tam A, Teemer CD, Thaller C, Thompson CL, Varnam LR, Visel A, Whitlock RM, Wohnoutka PE, Wolke CK, Wong VY, Wood M, Yaylaoglu MB, Young RC, Youngstrom BL, Yuan XF, Zhang B, Zwingman TA, Jones AR. 2007. Genome-wide atlas of gene expression in the adult human brain. Nature 445:168–176.

Magnain C, Augustinack JC, Reuter M, Wachinger C, Frosch MP, Ragan T, Akkin T, Wedeen VJ, Boas DA, Fischl B. 2014. Blockface histology with optical coherence tomography: a comparison with Nissl staining. NeuroImage 84:524–533.

Magnain C, Augustinack JC, Konukoglu E, Frosch MP, Sakadzic S, Varjabedian A, Garcia N, Wedeen VJ, Boas DA, Fischl B. 2015. Optical coherence tomography visualizes neurons in human entorhinal cortex. Neurophotonics 2:015004.

Mai JK, Paxinos G, Voss T. 2008. Atlas of the human brain, 3rd ed. New York: Elsevier Science.

Mazzotta J, Toga A, Evans A, Fox P, Lancaster J, Zilles K, Woods R, Paus T, Simpson G, Pike B, Holmes C, Collins L, Thompson P, MacDonald D, Iacoboni M, Schormann T, Amunts K, Palomero-Gallagher N, Geyer S, Parsons L, Narr K, Kabani N, Le Goualher G, Boomsma D, Cannon T, Kawashima R, Mazoyer B. 2001. A probabilistic atlas and reference system for the human brain: International Consortium for Brain Mapping (ICBM). Phil Trans R Soc Lond B Biol Sci 356:1293–1322.

Miller JD, Ding SL, Sunkin SM, Smith KA, Ng L, Szafer A, Ebbert A, Riley ZL, Royall JJ, Aiona K, Arnold JM, Bennett C, Bertagnolli D, Brouner K, Butler S, Caldejon S, Carey A, Cuhaciyan C, Dailey RA, Dee N, Dolbeare TA, Facer BA, Feng D, Fliss TP, Gee G, Goldy J, Gourley L, Gregor BW, Gu G, Howard RE, Jochim JM, Kuan CL, Lau C, Lee CK, Lee F, Lemon TA, Lesnar P, McMurray B, Mastan N, Mosqueda N, Nalau-Cecchini T, Ngo NK, Nyhus J, Olde A, Olson E, Parente J, Parker KD, Parry SE, Stevens A, Pletikos M, Reding M, Roll K, Sandman D, Sarreal M, Shapouri S, Shapovalova NV, Shen E, Sjoquist N, Slaughterbeck CR, Smith M, Sodt AJ, Williams D, Zollei L, Fischl B, Gerstein MB, Geschwind DH, Glass IA, Hawrylycz MJ, Hevritt RF, Huang H, Jones AR, Knowles JA, Levitt P, Phillips JW, Sestan N, Wohnoutka P, Dang C, Bernard A, Hohmann JG, Levin ES. 2014. Transcriptional landscape of the prenatal human brain. Nature 508:199–206.

Miller KL, McNab JA, Jbabdi S, Douaud G. 2012. Diffusion tractography of post-mortem human brains: optimization and comparison of spin echo and steady-state free precession techniques. NeuroImage 59:2284–2297.

Morecraft RJ, Rockland KS, Van Hoesen GW. 2000. Localization of area prostriata and its projection to the cingulate motor cortex in the rhesus monkey. Cereb Cortex 10:192–203.

Morel A. 2007. Stereotactic atlas of the human thalamus and basal ganglia. New York: Informa Healthcare USA.

Morel A, Gallay MN, Baechler A, Wyss M, Gallay DS. 2013. The human insula: architectonic organization and post-mortem MRI registration. NeuroImage 84:455–466.

Mori S, Crain BJ, Chacko VP, van Zijl PC. 1999. Three-dimensional tracking of axonal projections in the brain by magnetic resonance imaging. Ann Neurol 45:265–269.

Naidich TP, Duvernoy HM, Delman BN, Sorensen AG, Kollias SS, Haacke EM. 2008. Duvernoy's atlas of the human brain stem and cerebellum: high-field MRI, surface anatomy, internal structure, vascularization and 3D sectional anatomy. Vienna: Springer.

Nimchinsky EA, Vogt BA, Morrison JH, Hof PR. 1997. Neurofilament and calcium-binding proteins in the human cingulate cortex. J Comp Neurol 384:597–620.

Nowinski W, Chua BC. 2013. Bridging neuroanatomy, neuroradiology and neurology: three-dimensional interactive atlas of neurological disorders. Neurorad J 26:252–262.

Öngür D, Ferry AT, Price JL. 2003. Architectonic subdivision of the human orbitofrontal cortex. J Comp Neurol 460:425–449.

Papp EA, Leergaard TB, Calabrese E, Johnson GA, Bjaalie JG. 2014. Waxholm space atlas of the Sprague Dawley rat brain. NeuroImage 97:374–386.

Pascual B, Masdeu JC, Hollenbeck M, Makris N, Insauti R, Ding SL, Dickerson BC. 2015. Large-scale brain networks of the human left temporal pole: a functional connectiv-ity MRI study. Cereb Cortex 25:680–702.
Paxinos G, Huang XF, Sengul G, Watson C. 2012. Organization of human brainstem nuclei. In: Mai JK, Paxinos G, editors. The human nervous system, 3rd ed. New York: Elsevier. p 326–327.

Petrides M. 2012. The human cerebral cortex: an MRI atlas of the sulci and gyri in MNI stereotaxic space. New York: Elsevier.

Petrides M, Pandya DN. 2012. The frontal cortex.In: Mai JK, Paxinos G, editors. The human nervous system, 3rd ed. New York: Elsevier. p 943–987.

Roemer PB, Edelstein WA, Hayes CE, Souza SP, Mueller OM. 1990. The NMR phased array. Magn Reson Med 16: 192–225.

Saleem KS, Logothetis NK. 2012. A combined MRI and histology atlas of the rhesus monkey brain in stereotaxic coordinates, 2nd ed. San Diego: Academic Press.

Sarkisov SA, Filimonoff IN, Kononova EP, Preobraschenskaja IS, Kukuew LA. 1955. Atlas of the cytoarchitectonics of the human cerebral cortex. Moscow: Medgiz.

Shattuck DW, Adisetiyo V, Hojatkashani C, Salamon G, Narr KL, Poldrack RA, Bilder RM, Toga AW. 2008. Construction of a 3D probabilistic atlas of human cortical structures. NeuroImage 39:1064–1080.

Simić G, Hof PR. 2015. In search of the definitive Brodmann’s map of cortical areas in human. J Comp Neurol 523:5–14.

Sternberger LA, Sternberger NH. 1983. Monoclonal antibodies distinguish phosphorylated and non-phosphorylated forms of neurofilaments in situ. Proc Natl Acad Sci U S A 80:6126–6130.

Talairach J, Tournoux P. 1988. Co-planar stereotaxic atlas of the human brain. New York: Thieme Medical Publishers.

Toga AW, Thompson PM, Mori S, Amunts K, Zilles K. 2006. Towards multimodal atlases of the human brain. Nat Rev Neurosci 7:952–966.

Uylings HB, Rajkowska G, Sanz-Arigita E, Amunts K, Zilles K. 2005. Consequences of large interindividual variability for human brain atlases: converging macroscopic imaging and microscopical neuroanatomy. Anat Embryol 210: 423–431.

Van Essen DC, Lewis JW, Drury HA, Hadjikhani N, Tootell RB, Bakircioglu M, Miller Ml. 2001. Mapping visual cortex in monkeys and humans using surface-based atlases. Vision Res 41:1359–1378.

Vogt BA, Palomero-Gallagher N. 2012. Cingulate cortex.In: Mai JK, Paxinos G, editors. The human nervous system, 3rd ed. New York: Elsevier. p 943–987.

Vogt BA, Nimchinsky EA, Vogt LJ, Hof PR. 1995. Human cingulate cortex: surface features, flat maps, and cytoarchitecture. J Comp Neurol 359:490–506.

Vogt BA, Vogt LJ, Perl DP, Hof PR. 2001. Cytology of human caudomedial cingulate, retrosplenial, and caudal parahippocampal cortices. J Comp Neurol 438:353–376.

Vogt BA, Hof PR, Zilles K, Vogt LJ, Herold C, Palomero-Gallagher N. 2013. Cingulate area 32 homologies in mouse, rat, macaque and human: cytoarchitecture and receptor architecture. J Comp Neurol 521:4189–4204.

von Economo C. 1927. L’architecture cellulaire normale de l’ecorce cerebrale. Paris, Masson.

von Economo C, Koskinas GN. 1925. Die Cytoarchitektonik der Hirnrinde des erwachsenen Menschen. Berlin: Springer.

Wang H, Zhu J, Reuter M, Vinke LN, Yendiki A, Boas DA, Fischl B, Akkin T. 2014. Cross-validation of serial optical coherence scanning and diffusion tensor imaging: a study on neural fiber maps in human medulla oblongata. NeuroImage 100:395–404.

Wang R, Benner T, Soresen AG, Wedeen VJ. 2007. Diffusion Toolkit: a software package for diffusion imaging data processing and tractography. Proceedings of 15th Annual Meeting of International Society for Magnetic Resonance in Medicine, p 3720.

Wright SM, Wald LL. 1997. Theory and application of array coils in MR spectroscopy. NMR Biomed 10:394–410.

Yu HH, Chaplin TA, Davies AJ, Verma R, Rosa MG. 2012. A specialized area in limbic cortex for fast analysis of peripheral vision. Curr Biol 22:1351–1357.

Zilles K, Amunts K. 2009. Receptor mapping: architecture of the human cerebral cortex. Curr Opin Neurobiol 20:331–335.

Zilles K, Amunts K. 2010. Centenary of Brodmann’s map—conception and fate. Nat Rev Neurosci 11:139–145.

Zilles K, Amunts K. 2013. Individual variability is not noise. Trends Cogn Sci 17:153–155.

Zilles K, Palomero-Gallagher N, Gräf Bel D, Schöpfer P, Cremer M, Woods R, Amunts K, Axer M. 2016. High-resolution fiber and fiber tract imaging using polarized light microscopy in the human, monkey, rat, and mouse brain.In: Rockland KS, editor. Axons and brain architecture. San Diego, CA: Elsevier. p 369–389.
### TABLE 3.
Whole Brain Structure Ontology and Abbreviations

| Acronym | Description |
|---------|-------------|
| NT      | neural tube |
| Br      | brain       |
| F       | forebrain (prosencephalon) |
| FGM     | gray matter of forebrain |
| Tel     | telencephalon |
| Cx      | cerebral cortex |
| NCx     | neocortex (isocortex) |
| FCx     | frontal neocortex |
| PFC     | prefrontal cortex |
| A10     | frontal polar cortex (area 10) |
| A10m    | medial subdivision of area 10 |
| A10l    | lateral subdivision of area 10 |
| A10o    | orbital subdivision of area 10 |
| DFC     | dorsolateral prefrontal cortex |
| A8      | caudal portion of DFC (area 8, area FC) |
| A8ld    | laterodorsal subdivision of area 8 |
| A8lv    | lateroventral subdivision of area 8 |
| A8m     | medial subdivision of area 8 |
| A9      | rostroventral portion of DFC (area 9) |
| A9l     | lateral subdivision of area 9 |
| A9m     | medial subdivision of area 9 |
| A9/46   | intermediate portion of DFC (area 9/46) |
| A9/46d  | dorsal subdivision of A9/46 |
| A9/46v  | ventral subdivision of A9/46 |
| A46     | rostroventral portion of DFC (area 46) |
| A46d    | dorsal subdivision of area 46 |
| A46v    | ventral subdivision of area 46 |
| VFC     | ventrolateral prefrontal cortex (Broca's area) |
| A44     | caudal portion of VFC (area 44) |
| A44d    | dorsal subdivision of area 44 |
| A44v    | ventral subdivision of area 44 |
| A44op   | opercular subdivision of area 44 |
| A45     | rostral portion of VFC (area 45) |
| A45r    | rostral subdivision of A45 |
| A45c    | caudal subdivision of A45 |
| A45op   | opercular subdivision of A45 |
| OFC     | orbital frontal cortex |
| OFCm    | medial orbital frontal cortex (area 14) |
| A14r    | rostral subdivision of area 14 |
| A14c    | caudal subdivision of area 14 |
| OFCi    | intermediate orbital frontal cortex |
| A11     | rostral division of OFCi (area 11) |
| Abbreviation | Description |
|--------------|-------------|
| A11m         | medial subdivision of area 11 |
| A11l         | lateral subdivision of area 11 |
| A13          | caudal division of OFCi (area 13) |
| A13m         | medial subdivision of area 13 |
| A13l         | lateral subdivision of area 13 |
| OFCi         | lateral orbital frontal cortex (area 12/47) |
| A12/47m      | medial subdivision of area 12/47 |
| A12/47l      | lateral subdivision of area 12/47 |
| PoFC         | posterior frontal cortex (motor cortex) |
| M1C (A4)     | primary motor cortex (area M1, area 4, area FA) |
| PMC          | premotor cortex (area 6, area FB) |
| A6ld         | laterodorsal subdivision of area 6 |
| A6lv         | lateroventral subdivision of area 6 |
| A6m          | medial subdivision of area 6 (area MII) |
| A6/32        | area 6/32 |
| PCx          | parietal neocortex |
| S1C (A3,1,2) | primary somatosensory cortex (area S1, areas 3,1,2) |
| ScC (A43)    | subcentral cortex (gustatory cortex, area 43) |
| PoPC         | posterior parietal cortex |
| SPC          | posterodorsal (superior) parietal cortex |
| A5           | rostral division of SPC (area 5) |
| A5ci         | cingulate subdivision of area 5 |
| A5l          | lateral subdivision of area 5 |
| A5m          | medial subdivision of area 5 |
| A7           | caudal division of SPC (area 7, area PE) |
| A7r          | rostral subdivision of area 7 |
| A7m          | medial subdivision of area 7 |
| A7c          | caudal subdivision of area 7 |
| A7pc         | postcentral subdivision of area 7 |
| A7ip         | intraparietal subdivision of area 7 (A7ip) |
| A7ipr        | area 7ip, rostral part (A7ipr) |
| A7ipc        | area 7ip, caudal part (A7ipc) |
| IPC          | posteroventral (inferior) parietal cortex |
| A40          | rostral division of IPC (area 40, area PF) |
| A40rd        | rostroventral subdivision of area 40 |
| A40rv        | rostroventral subdivision of area 40 |
| A40in        | inferior subdivision of area 40 |
| A40/39       | intermediate division of IPC (area 40/39, area PFG) |
| A40/39r      | rostral subdivision of area 40/39 |
| A40/39c      | caudal subdivision of area 40/39 |
| A39          | caudal division of IPC (area 39, area PG) |
| A39r         | rostral subdivision of area 39 |
| A39c         | caudal subdivision of area 39 |
| RI           | retroinsular cortex |
| TCx          | temporal neocortex |
| DLTC         | dorsolateral temporal neocortex |
| A1C          | primary auditory cortex (core) |
| A41   | main portion of A1C (area TC, area 41) |
|-------|-------------------------------------|
| A1Cr  | rostral portion of A1C              |
| A42   | secondary auditory cortex (belt, area 42, area TB) |
| SLTC  | superolateral temporal cortex      |
| ASTC (A22r) | anterior (rostral) superior temporal cortex (area 22r) |
| ISTC (A22i) | intermediate superior temporal cortex (area 22i) |
| STC (A22c) | posterior (caudal) superior temporal cortex (area 22c) |
| PSTC (A22p) | polysensory temporal cortex (area 22p) |
| A22pr | rostral division of 22p (area 22pr) |
| A22pi | intermediate division of 22p (area 22pi) |
| A22pc | caudal division of 22p (area 22pc) |
| PI    | parainsular cortex (area 52)       |
| VLTC  | ventrolateral temporal neocortex   |
| MTC (A21) | midlateral temporal cortex (area TEd, area 21) |
| A21r  | rostral subdivision of area 21     |
| A21i  | intermediate subdivision of area 21 |
| A21c  | caudal subdivision of area 21      |
| ITC (A20) | inferolateral temporal cortex (area TEv, area 20) |
| A20r  | rostral subdivision of area 20     |
| A20i  | intermediate subdivision of area 20 |
| A20c  | caudal subdivision of area 20      |
| MITC  | midinferior (fusiform) temporal cortex |
| A36   | rostral division of MITC (area 36)  |
| A36r  | rostral subdivision of area 36     |
| A36c  | caudal subdivision of area 36      |
| TF    | caudal division of MITC (area TF)  |
| PPHC  | posterior parahippocampal cortex   |
| TH    | medial division of PPHC (area TH)  |
| TL    | lateral division of PPHC (area TL) |
| TFO   | medial temporal-occipital cortex (area TFO) |
| TFO-m | area TFO, medial part              |
| TFO-l | area TFO, lateral part (fusiform face area) |
| A37   | lateral temporal-occipital cortex (area 37) |
| A38   | temporal polar cortex (area TG, area 38) |
| V5/MT | area V5 (mid temporal area)        |
| Ocx   | occipital neocortex                |
| Pro   | area prostriata                    |
| V1C   | primary visual cortex (striate cortex, area V1/17, area OC) |
| ESOC  | extrastriate occipital cortex      |
| Vx    | area x of visual cortex            |
| V2 (A18) | parastriate cortex (area V2, area 18, area OB) |
| PSC (A19) | peristriate cortex (area 19, area OA) |
| V3    | area V3 of peristriate cortex      |
| VP    | area VP (V3V) of peristriate cortex |
| V3A   | area V3A of peristriate cortex     |
| V4D   | area V4D of peristriate cortex     |
| V4    | area V4 of peristriate cortex      |
| V3B  | area V3B of peristriate cortex |
|------|--------------------------------|
| V6   | area V6 of peristriate cortex |
| V6A/PO | area V6 of peristriate cortex (parieto-occipital area) |
| V7   | area V7 of peristriate cortex |
| LO   | lateral occipital area |
| ICx  | insular neocortex |
| Idg  | dysgranular insular cortex |
| RIdg | rostral dysgranular insular cortex |
| Cldg | caudal dysgranular insular cortex |
| Ig   | granular insular cortex |
| Rlg  | rostral granular insular cortex |
| Clg  | caudal granular insular cortex |
| CCx  | cingulate neocortex |
| MFC (ACC) | anterior (rostral) cingulate cortex (ventromedial prefrontal cortex) |
| A24  | ventral division of MFC (area 24, area LA) |
| A32  | dorsorostral division of MFC (area 32) |
| A25  | subgenual (subcallosal) division of MFC (area 25, area FL) |
| MCC  | midcingulate cortex |
| A24mc | ventral division of MCC (area 24mc) |
| A32mc | dorsal division of MCC (area 32mc) |
| PCC  | posterior (caudal) cingulate cortex |
| A23  | ventral division of PCC (area 23, area LC2) |
| A31  | dorsal division of PCC (area 31, area LC1) |
| PACx | periallocortex |
| PArCx | periarchicortex |
| A35  | perirhinal cortex (area 35) |
| A35r | rostral subdivision of area 35 |
| A35c | caudal subdivision of area 35 |
| EC   | entorhinal cortex |
| LEC  | lateral (anterior) entorhinal cortex |
| EO   | olfactory part of entorhinal cortex |
| ER   | rostral part of entorhinal cortex |
| ELR  | laterorostral part of entorhinal cortex |
| EMI  | medial intermediate part of entorhinal cortex |
| MEC  | medial (posterior) entorhinal cortex |
| ELI  | lateral intermediate part of entorhinal cortex |
| Ec   | caudal part of entorhinal cortex |
| ECL  | caudal limiting part of entorhinal cortex |
| ELC  | latero- caudal part of entorhinal cortex |
| PaS  | parasubicular cortex (parasubiculum) |
| PaSb | proximal parasubiculum |
| PaSa | distal parasubiculum |
| PrS  | presubicular cortex (presubiculum) |
| PrSr | rostral presubiculum |
| PrSc | caudal presubiculum (postsubiculum) |
| RSC  | retrosplenial cortex |
| A29  | area 29 of retrosplenial cortex |
| A30   | area 30 of retrosplenial cortex |
|------|---------------------------------|
| PPCx | peripaleocortex                 |
| Iag  | agranular insular cortex (area Ia) |
| Fl   | frontal agranular insular cortex (area Fl) |
| TI   | temporal agranular insular cortex (area Ti) |
| ACx  | allocortex                      |
| ArCx | archicortex                     |
| HIP  | hippocampus (hippocampal formation) |
| DG   | dentate area (dentate gyrus)     |
| DGU  | uncal dentate gyrus             |
| DGUmo| molecular layer of uncal dentate gyrus |
| DGUgr| granular layer of uncal dentate gyrus |
| DGUsg| subgranular zone of uncal dentate gyrus |
| DGUpf| polymorphic layer of uncal dentate gyrus |
| DGR  | rostral dentate gyrus           |
| DGRmo| molecular layer of rostral dentate gyrus |
| DGRgr| granular layer of rostral dentate gyrus |
| DGRsg| subgranular zone of rostral dentate gyrus |
| DGRpf| polymorphic layer of rostral dentate gyrus |
| DGC  | caudal dentate gyrus            |
| DGCmo| molecular layer of caudal dentate gyrus |
| DGCgr| granular layer of caudal dentate gyrus |
| DGCsg| subgranular zone of caudal dentate gyrus |
| DGCpf| polymorphic layer of caudal dentate gyrus |
| Hipp | hippocampal proper              |
| CA1  | CA1 region of hippocampus       |
| CA1U | uncal CA1                       |
| CA1UsIm| stratum lacunosum-moleculare of uncal CA1 |
| CA1Usmo| stratum moleculare of uncal CA1 |
| CA1Usla| stratum lacunosum of uncal CA1 |
| CA1Usr | stratum radiatum of uncal CA1  |
| CA1Usp | stratum pyramidale of uncal CA1 |
| CA1Uso | stratum oriens of uncal CA1    |
| CA1R  | rostral CA1                     |
| CA1RsIm| stratum lacunosum-moleculare of rostral CA1 |
| CA1Rsro| stratum moleculare of rostral CA1 |
| CA1Rsra| stratum lacunosum of rostral CA1 |
| CA1Rsr | stratum radiatum of rostral CA1 |
| CA1Rsp | stratum pyramidale of rostral CA1 |
| CA1Rso | stratum oriens of rostral CA1  |
| CA1C  | caudal CA1                      |
| CA1Cslm| stratum lacunosum-moleculare of caudal CA1 |
| CA1Csmo| stratum moleculare of caudal CA1 |
| CA1Csla| stratum lacunosum of caudal CA1 |
| CA1Csr | stratum radiatum of caudal CA1  |
| CA1Csp | stratum pyramidale of caudal CA1 |
| CA1Cso | stratum oriens of caudal CA1   |
| CA2         | CA2 region of hippocampus |
|------------|---------------------------|
| CA2U       | uncal CA2                 |
| CA2Uslm    | stratum lacunosum-moleculare of uncal CA2 |
| CA2Usmo    | stratum moleculare of uncal CA2 |
| CA2Usla    | stratum lacunosum of uncal CA2 |
| CA2Usr     | stratum radiatum of uncal CA2 |
| CA2Usp     | stratum pyramidale of uncal CA2 |
| CA2uso     | stratum oriens of uncal CA2 |
| CA2R       | rostral CA2               |
| CA2Rslm    | stratum lacunosum-moleculare of rostral CA2 |
| CA2Rsmo    | stratum moleculare of rostral CA2 |
| CA2Rsla    | stratum lacunosum of rostral CA2 |
| CA2Rsr     | stratum radiatum of rostral CA2 |
| CA2Rsp     | stratum pyramidale of rostral CA2 |
| CA2Rso     | stratum oriens of rostral CA2 |
| CA2C       | caudal CA2                |
| CA2Cslm    | stratum lacunosum-moleculare of caudal CA2 |
| CA2Csmo    | stratum moleculare of caudal CA2 |
| CA2Csla    | stratum lacunosum of caudal CA2 |
| CA2Csr     | stratum radiatum of caudal CA2 |
| CA2Csp     | stratum pyramidale of caudal CA2 |
| CA2Cso     | stratum oriens of caudal CA2 |
| CA3        | CA3 region of hippocampus |
| CA3U       | uncal CA3                 |
| CA3Uslm    | stratum lacunosum-moleculare of uncal CA3 |
| CA3Usmo    | stratum moleculare of uncal CA3 |
| CA3Usla    | stratum lacunosum of uncal CA3 |
| CA3Usr     | stratum radiatum of uncal CA3 |
| CA3Usi     | stratum lucidum of uncal CA3 |
| CA3Usp     | stratum pyramidale of uncal CA3 |
| CA3uso     | stratum oriens of uncal CA3 |
| CA3R       | rostral CA3               |
| CA3Rslm    | stratum lacunosum-moleculare of rostral CA3 |
| CA3Rslo    | stratum moleculare of rostral CA3 |
| CA3Rsia    | stratum lacunosum of rostral CA3 |
| CA3Rsr     | stratum radiatum of rostral CA3 |
| CA3Rsi     | stratum lucidum of rostral CA3 |
| CA3Rsp     | stratum pyramidale of rostral CA3 |
| CA3Rso     | stratum oriens of rostral CA3 |
| CA3C       | caudal CA3                |
| CA3Cslm    | stratum lacunosum-moleculare of caudal CA3 |
| CA3Csmo    | stratum moleculare of caudal CA3 |
| CA3Csla    | stratum lacunosum of caudal CA3 |
| CA3Csr     | stratum radiatum of caudal CA3 |
| CA3Csi     | stratum lucidum of caudal CA3 |
| CA3Csp     | stratum pyramidale of caudal CA3 |
| CA3Cso     | stratum oriens of caudal CA3 |
### TABLE 3. Continued

| Abbreviation | Description |
|--------------|-------------|
| CA4          | CA4 region of hippocampus |
| CA4Upy       | pyramidal cells of uncal CA4 |
| CA4Rpy       | pyramidal cells of rostral CA4 |
| CA4Cpy       | pyramidal cells of caudal CA4 |
| Sub          | subiculum |
| S-U          | uncal subiculum |
| S-R          | rostral subiculum |
| S-C          | caudal subiculum |
| ProS         | prosubiculum |
| ProU         | uncal prosubiculum |
| ProR         | rostral prosubiculum |
| ProC         | caudal prosubiculum |
| SuS          | supracallosal subiculum |
| IG           | indusium griseum |
| TT           | taenia tecta |
| PalCx        | paleocortex (semicortex) |
| OB           | olfactory bulb |
| AON          | anterior olfactory nucleus |
| NLOT         | nucleus of lateral olfactory tract |
| OT           | olfactory tubercle |
| LOA          | lateral olfactory area |
| LOAlc        | lightly-stained cell islands of lateral olfactory area |
| LOAdc        | darkly-stained cell islands of lateral olfactory area |
| Pir          | piriform cortex |
| Pir1         | layer I of piriform cortex |
| Pir2         | layer II of piriform cortex |
| Pir3         | layer III of piriform cortex |
| PEA          | piriform-entorhinal-amygdaloid area |
| PEA1         | layer I of piriform-entorhinal-amygdaloid area |
| PEA2         | layer II of piriform-entorhinal-amygdaloid area |
| PEA3         | layer III of piriform-entorhinal-amygdaloid area |
| CN           | cerebral nuclei |
| AMY          | amygdaloid complex |
| AAA          | anterior amygdaloid area |
| AAAAd        | dorsal part of AAA |
| AAAv         | ventral part of AAA |
| CEN          | central nuclear group |
| CEm          | medial subdivision of central nucleus |
| CEmd         | dorsal part of CEm |
| CEmv         | ventral part of CEm |
| CEI          | lateral subdivision of central nucleus |
| CEIap        | apical part of CEI |
| CEIca        | capsular part of CEI |
| CEIpc        | paracapsular part of CEI |
| CEIcn        | central part of CEI |
| CMN          | corticomedial nuclear group |
| Acronym | Description                                          |
|---------|------------------------------------------------------|
| Co      | cortical amygdaloid nuclei                          |
| CoA     | anterior cortical nucleus                           |
| CoAd    | dorsal subdivision of CoA                           |
| CoAv    | ventral subdivision of CoA                          |
| CoA-m   | marginal layer of anterior cortical nucleus         |
| CoP     | posterior cortical nucleus                          |
| CoPd    | dorsal subdivision of CoP                           |
| CoPv    | ventral subdivision of CoP                          |
| CoP-m   | marginal layer of posterior cortical nucleus        |
| Me      | medial nucleus                                      |
| MeR     | rostral subdivision of medial nucleus              |
| MeC     | caudal subdivision of medial nucleus               |
| MeCd    | dorsal part of caudal medial nucleus               |
| MeCv    | ventral part of caudal medial nucleus               |
| Me-m    | marginal layer of medial amygdaloid nucleus        |
| AHA     | amygda1ohippocampal area                            |
| AHAmc   | magnocellular part of amygdalohippocampal area     |
| AHApc   | parvocellular part of amygdalohippocampal area      |
| AHA-m   | marginal layer of amygdalohippocampal area          |
| BLN     | basolateral nuclear group                           |
| La      | lateral nucleus                                     |
| LaD     | dorsal division of lateral nucleus                 |
| LaDr    | dorsal rostral subdivision of lateral nucleus      |
| LaDi    | dorsal lateral subdivision of lateral nucleus      |
| LaCom   | comb-like part of LaDi                              |
| LaDm    | dorsal medial subdivision of lateral nucleus       |
| LaI     | intermediate division of lateral nucleus           |
| LaV     | ventral division of lateral nucleus                |
| LaVI    | ventral lateral subdivision of lateral nucleus     |
| LaVm    | ventral medial subdivision of lateral nucleus      |
| LaVglo  | glomerular subdivision of lateral nucleus          |
| BL      | basolateral nucleus (basal nucleus)                |
| BLD     | dorsal (magnocellular) division of basolateral nucleus |
| BLDI    | dorsal lateral subdivision of basolateral nucleus  |
| BLI     | intermediate division of basolateral nucleus       |
| BLV     | ventral (parvocellular) division of basolateral nucleus |
| BLVI    | ventral lateral subdivision of basolateral nucleus |
| BLVm    | ventral medial subdivision of basolateral nucleus  |
| BM      | basomedial nucleus (accessory basal nucleus)       |
| BMD     | dorsal division of basomedial nucleus               |
| BMDI    | dorsolateral subdivision of basomedial nucleus      |
| BMDm    | dorsomedial (magnocellular) subdivision of basomedial nucleus |
| BMV     | ventral division of basomedial nucleus              |
| BMVI    | ventrolateral (parvocellular) subdivision of basomedial nucleus |
| BMVvm   | ventromedial subdivision of basomedial nucleus      |
| BMm     | medial division of basomedial nucleus               |
| BV      | basoventral nucleus                                 |
| Abbreviation | Description |
|--------------|-------------|
| PL           | paralaminar nucleus |
| PLglo        | glomerular part of paralaminar nucleus |
| En           | endopiriform nucleus |
| INA          | intercalated nucleus of amygdala |
| IMG          | intramedullary gray of the amygdala |
| ATA          | amygdaloid transition areas |
| AHTA         | amygdalohippocampal transition area |
| ASTA         | amygdalostrial transition area |
| ACTA         | amygdalocortical (corticoamygdaloid) transition area |
| SA           | supra-amygdaloid area |
| EXA          | extended amygdala |
| BNST         | bed nucleus of stria terminalis |
| BNSTm        | medial subdivision of BNST |
| BSTmr        | rostral subdivision of BNSTm |
| BSTmc        | caudal subdivision of BNSTm |
| BSTmcl       | lateral subdivision of BNSTmcl |
| BSTmm        | medial subdivision of BNSTmm |
| BSTmv        | ventral subdivision of BNSTmv |
| BNSTl        | lateral subdivision of BNSTl |
| BSTlj        | juxtacapsular subdivision of BNSTl |
| BSTld        | dorsal subdivision of BNSTld |
| BSTlv        | ventral subdivision of BNSTlv |
| BSTlcn       | central subdivision of BNSTlcn |
| BSTlcn-s     | shell of central subdivision of BNSTlcn |
| BSTlc        | caudal subdivision of BNSTlc |
| BSTlcm       | medial subdivision of BNSTlcm |
| BSTlcd       | dorsal subdivision of BNSTlcd |
| BSTlcv       | ventral subdivision of BNSTlcv |
| BNSTsc       | supracapsular division of BNST |
| BSTsc        | lateral column of BNSTsc |
| BSTscm       | medial column of BNSTscm |
| BNSTin       | intercalated nuclei of BNST |
| SLEA         | sublenticular extended amygdala |
| SLEAm        | medial division of sublenticular extended amygdala |
| SLEAc        | central division of sublenticular extended amygdala |
| IPAC         | interstitial nucleus of posterior limb of anterior commissure |
| BN           | basal nuclei (basal ganglia) |
| STR          | striatum |
| Ca           | caudate nucleus |
| CaH          | head of caudate |
| CaB          | body of caudate |
| CaT          | tail of caudate |
| Eca          | peri-caudate ependymal and subependymal zone |
| CaPu         | caudate-putamen cell bridges |
| Pu           | putamen |
| PuR          | rostral putamen |
| PuRv         | ventral part of rostral putamen |
| Abbreviation | Description                                      |
|-------------|-----------------------------------------------|
| PuC         | caudal putamen                                |
| Plld        | laterodorsal part of putamen                 |
| Pint        | intermediate part of putamen                 |
| Pmv         | medioventral part of putamen                 |
| PuPV        | posteroventral putamen                        |
| PuMG        | marginal subdivision (cell groups) of putamen |
| NAC         | nucleus accumbens                            |
| NACc        | core of nucleus accumbens                    |
| NACcl       | lateral portion of the core                  |
| NACcm       | medial portion of the core                   |
| NACs        | shell of nucleus accumbens                   |
| NACsl       | lateral portion of the shell                 |
| NACsi       | intermediate portion of the shell            |
| NACsm       | medial portion of the shell                  |
| GP          | globus pallidus                               |
| GPe         | external segment of globus pallidus           |
| GPi         | internal segment of globus pallidus           |
| GPic        | central portion of GPi                       |
| GPip        | peripheral portion of GPi                    |
| EnPN        | entopeduncular nucleus                        |
| VeP         | Ventral pallidus                              |
| Cla         | claustrum                                     |
| CLd         | Dorsal claustrum                              |
| CLv         | ventral claustrum                             |
| Clt         | temporal claustrum                            |
| BF          | basal forebrain                               |
| SEP         | septal nuclei                                 |
| MSN         | medial septal nucleus                         |
| LSN         | lateral septal nucleus                        |
| LSnD        | dorsal division of lateral septal nucleus    |
| LSnI        | intermediate division of lateral septal nucleus |
| LSnV        | ventral division of lateral septal nucleus   |
| CSN         | caudal septal nucleus                         |
| SFi         | septofimbrial nucleus                         |
| TSN         | triangular septal nucleus                     |
| SHi         | septohipocampal nucleus                       |
| Ld          | lambdoid septal zone                          |
| Pld         | paralambdoid septal nucleus                   |
| SHy         | septohypothalamic nucleus                     |
| BNM         | basal nucleus of Meynert                      |
| BNMI        | lateral cell groups of basal nucleus          |
| BNMM        | medial cell groups of basal nucleus           |
| NDB         | nucleus of diagonal band                      |
| NDBv        | vertical subdivision of nucleus of diagonal band |
| NDBh        | horizontal subdivision of nucleus of diagonal band |
| NSP         | nucleus subputaminalis                        |
| IsCj        | islands of Calleja                            |
| Abbreviation | Description |
|--------------|-------------|
| IsCjm        | major island of Calleja |
| IsCJs        | scattered islands of Calleja |
| SI           | substantia innominata |
| SI-pc        | lightly-stained parvocellular islands of SI |
| SI-nc        | darkly-stained nanocellular islands of SI |
| Die          | diencephalon |
| THM          | thalamus |
| DTH          | dorsal thalamus |
| ANC          | anterior nuclear complex of thalamus |
| AD           | anterodorsal nucleus of thalamus |
| AM           | anteromedial nucleus of thalamus |
| AV           | anteroventral nucleus of thalamus |
| LD           | lateral dorsal nucleus of thalamus |
| MNC          | medial nuclear complex of thalamus |
| MD           | mediadorsal nucleus of thalamus |
| MDd          | densocellular (paralamellar) division of MD |
| MDm          | magnocellular (medial) division of MD |
| MDam         | anteromedial large-celled island of MD |
| MDI          | multiform (lateral) division of MD |
| MDc          | parvocellular (central) division of MD |
| MDv          | ventral division of MD |
| Re           | reuniens nucleus (medioventral nucleus) of thalamus |
| Pt           | parataenial nucleus of thalamus |
| LNC          | lateral nuclear complex of thalamus |
| DLN          | dorsal group of lateral nucleus |
| LP           | lateral posterior nucleus of thalamus |
| Pul          | pulvinar of thalamus |
| Pulr         | anterior nucleus of pulvinar |
| Pulm         | medial nucleus of pulvinar |
| Pull         | lateral nucleus of pulvinar |
| Puli         | inferior nucleus of pulvinar |
| Pulil         | lateral subdivision of Puli |
| Pulim         | medial subdivision of Puli |
| VLN          | ventral group of lateral nucleus |
| VA           | ventral anterior nucleus of thalamus |
| VApr         | parvocellular division of VA |
| VAmc         | magnocellular division of VA |
| VL           | ventral lateral nucleus of thalamus |
| VLR          | rostral division of VL |
| VLC          | caudal division of VL |
| VLCD          | dorsal subdivision of VLC |
| VLCv         | ventral subdivision of VLC |
| VLCx         | medial subdivision of VLC (thalamic nucleus X) |
| VPT          | ventral posterior nucleus of thalamus |
| VPL          | ventral posterior lateral nucleus |
| VPLr         | rostral division of ventral posterior lateral nucleus |
| VPLc         | caudal division of ventral posterior lateral nucleus |
| Abbreviation | Description |
|--------------|-------------|
| VPM          | ventral posterior medial nucleus |
| VPmpc        | parvocellular division of VPM |
| VPI          | ventral posterior inferior nucleus |
| VMb          | basal ventral medial nucleus |
| VM           | ventral medial nucleus of thalamus |
| PoN          | posterior nuclear complex of thalamus |
| LG           | lateral geniculate nucleus |
| DLG          | dorsal lateral geniculate nucleus |
| DLGmc        | magnocellular layer of DLG |
| DLG1         | layer 1 of DLG |
| DLG2         | layer 2 of DLG |
| DLGpc        | parvocellular layer of DLG |
| DLG3         | layer 3 of DLG |
| DLG4         | layer 4 of DLG |
| DLG5         | layer 5 of DLG |
| DLG6         | layer 6 of DLG |
| DLGs         | S layer of DLG |
| DLGk         | koniocellular layer of DLG |
| PG           | pregeniculate nucleus |
| MG           | medial geniculate nuclei |
| DMG          | dorsal medial geniculate nucleus |
| DMGad        | anterodorsal subdivision of DMG |
| DMGpd        | posterodorsal subdivision of DMG |
| VMG          | ventral medial geniculate nucleus |
| MMG          | magnocellular (medial) nucleus |
| LimG         | limitans part of medial geniculate nucleus |
| Po           | posterior nucleus of thalamus |
| LSG          | limitans/suprageniculate nucleus |
| Lim          | limitans nucleus |
| SGN          | suprageniculate nucleus of thalamus |
| ILN          | intralaminar nuclear complex |
| AILN         | anterior group of intralaminar nuclei |
| CL           | central lateral nucleus of the thalamus |
| CLm          | medial division of central lateral nucleus |
| CLI          | lateral division of central lateral nucleus |
| CLs          | dorsal division of central lateral nucleus |
| CLc          | caudal division of central lateral nucleus |
| CeM          | central medial nucleus of thalamus |
| PC           | paracentral nucleus of thalamus |
| CD           | central dorsal nucleus of thalamus |
| PILN         | posterior group of intralaminar nuclei |
| CM           | centromedian nucleus of thalamus |
| CMI          | lateral division of centromedian nucleus of thalamus |
| CMm          | medial division of centromedian nucleus of thalamus |
| Pf           | parafascicular nucleus of thalamus |
| Pfl          | lateral division of parafascicular nucleus of thalamus |
| Pfm          | medial division of parafascicular nucleus of thalamus |
| Abbreviation | Description |
|--------------|-------------|
| SPF          | subparafascicular nucleus of thalamus |
| RPF          | retroparafascicular area of thalamus |
| Fa           | fasciculosis nucleus of thalamus |
| MiN          | midline nuclear complex |
| Rh           | rhomboid (central) nucleus of thalamus |
| PeVA         | periventricular area of thalamus |
| IAM          | interanteromedial nucleus of thalamus |
| IMD          | intermediodorsal nucleus of thalamus |
| ETH          | epithalamus |
| HN           | habenular nuclei |
| LHN          | lateral habenular nucleus |
| LHNmc        | magnocellular division of lateral habenular nucleus |
| LHNpc        | parvicellular division of lateral habenular nucleus |
| MHN          | medial habenular nucleus |
| PaV          | paraventricular nucleus |
| PaVr         | rostral subdivision of paraventricular nucleus |
| PaVc         | caudal subdivision of paraventricular nucleus |
| Pin          | pineal body |
| VTH          | ventral thalamus |
| FF           | nucleus of the field of Forel |
| ZI           | zona incerta |
| ZId          | zona incerta, dorsal division |
| ZIv          | zona incerta, ventral division |
| EnP          | endopeduncular nucleus |
| PSTh         | parasubthalamic nucleus |
| R            | reticular nucleus of thalamus |
| Rmc          | magnocellular division of reticular nucleus |
| Rpc          | parvocellular division of reticular nucleus (perireticular nucleus) |
| SubTH        | subthalamus |
| STH          | subthalamic nucleus |
| STHm         | medial portion of STH |
| STHId        | laterodorsal portion of STH |
| STHlv        | lateroventral portion of STH |
| HTH          | hypothalamus |
| HTHpo        | preoptic region of HTH |
| PeVpo        | periventricular nucleus, preoptic portion |
| DPe          | dorsal periventricular nucleus |
| AVPe         | anteroventral periventricular nucleus |
| AMPO         | anteromedial preoptic nucleus |
| MPA          | medial preoptic area |
| MPN          | medial preoptic nucleus |
| LPA          | lateral preoptic area |
| IMH          | intermediate (sexually dimorphic) hypothalamic nuclei |
| MnPO         | median preoptic nucleus |
| HTHso        | supraoptic region of HTH |
| PeVso        | periventricular nucleus, supraoptic portion |
| AHN          | anterior hypothalamic nucleus |
| AnHA | anterior hypothalamic area |
| PV  | paraventricular nucleus of hypothalamus |
| PVd | descending division of paraventricular nucleus |
| PVmc | magnocellular division of paraventricular nucleus |
| PVpc | parvicellular division of paraventricular nucleus |
| PVpoo | posterior division of paraventricular nucleus |
| UnN | uncinate nucleus |
| SCN | suprachiasmatic nucleus |
| SCNd | dorsal part of suprachiasmatic nucleus |
| SCNc | central part of suprachiasmatic nucleus |
| RCN | retrochiasmatic nucleus |
| SO | supraoptic nucleus |
| SOn | medial part of supraoptic nucleus |
| SOl | lateral part of supraoptic nucleus |
| LHAA | lateral hypothalamic area, anterior part |
| SuV | subventricular nucleus |
| SPZ | subparaventricular zone |
| HTHtub | tuberal region of HTH |
| PeVtub | periventricular nucleus, tuberal portion |
| JPLH | juxtaventricular lateral hypothalamic area |
| DHA | dorsal hypothalamic area |
| DMH | dorsomedial hypothalamic nucleus |
| DMHc | compact part of dorsomedial hypothalamic nucleus |
| DMHd | diffuse part of dorsomedial hypothalamic nucleus |
| VMH | ventromedial hypothalamic nucleus |
| VMHd | dorsal part of ventromedial hypothalamic nucleus |
| VMHv | ventral part of ventromedial hypothalamic nucleus |
| VMHc | central part of ventromedial hypothalamic nucleus |
| PMH | posteromedial hypothalamic nucleus |
| Arc | arcuate nucleus of hypothalamus |
| LT | lateral tuberal nuclei |
| LHA tub | lateral hypothalamic area, tuberal part |
| LHC | magnocellular nucleus of lateral hypothalamic area |
| LHCc | accessory secretory cells of lateral hypothalamus |
| PalHy | pallidohypothalamic area |
| NCN | nanocellular hypothalamic nucleus |
| ME | median eminence |
| MEEx | external portion of median eminence |
| MEI | internal portion of median eminence |
| HTHma | mammillary region of HTH |
| TM | tuberomammillary nucleus |
| SUM | supramammillary nucleus |
| MN | mammillary nucleus |
| MM | medial mammillary nucleus |
| MMI | lateral part of medial mammillary nucleus |
| MMm | medial part of medial mammillary nucleus |
| MMb | basal division of medial mammillary nucleus |
### TABLE 3. Continued

| Abbreviation | Description |
|--------------|-------------|
| LM           | lateral mammillary nucleus |
| PHN          | posterior hypothalamic nucleus |
| LHAp         | lateral hypothalamic area, posterior part |
| PeF          | perifornical nucleus |
| PMN          | premammillary nucleus |
| RMA          | retromammillary area |
| Pit          | pituitary body |
| FWM          | white matter of forebrain |
| FCFT         | forebrain commissural fiber tracts |
| ac           | anterior commissure |
| cc           | corpus callosum |
| ccr          | rostrum of corpus callosum |
| ccg          | genu of corpus callosum |
| ccg-mi       | forceps minor (frontalis) |
| ccb          | body of corpus callosum |
| ccb-r        | body of cc, rostral portion |
| ccb-i        | body of cc, intermediate portion |
| ccb-c        | body of cc, caudal portion |
| ccs          | splenium of corpus callosum |
| ccs-ma       | forceps major (occipitalis) |
| ccs-in       | forceps inferior |
| ccrd         | radiations of corpus callosum |
| tap          | tapetum of corpus callosum |
| hac          | habenular commissure |
| hic          | hippocampal commissure |
| dhic         | dorsal hippocampal commissure |
| vhic         | ventral hippocampal commissure |
| smc          | supramammillary commissure |
| FIFT         | forebrain ipsilateral fiber tracts |
| alv          | alveus |
| amtg         | amygdalotegmental tract |
| ar           | acoustic radiation |
| agb          | angular bundle |
| al           | ansa lenticularis |
| ap           | ansa peduncularis |
| af           | arcuate fasciculus |
| bx           | bundle X |
| cb           | cingulum bundle |
| cb-cx        | cingulum bundle in cingulate cortex |
| cb-tx        | cingulum bundle in temporal cortex |
| comb         | comb fibers |
| cor          | corona radiata |
| cor-a        | anterior portion of corona radiata |
| cor-s        | superior portion of corona radiata |
| cor-p        | posterior portion of corona radiata |
| cbu-sc       | corticobulbar tract, supracapsular part |
| cpa          | corticopallidal tract |
| Abbreviation | Description |
|--------------|-------------|
| cst          | corticostriate tract |
| dpa          | dentatopallidal tract |
| dlb          | diagonal band |
| dlf          | dorsal longitudinal fasciculus |
| doh          | dorsal occipital bundle |
| extC         | external capsule |
| emlgp        | external medullary lamina of globus pallidus |
| emth         | external medullary lamina of thalamus |
| extrC        | extreme capsule |
| fim          | fimbria |
| fx           | fornix |
| fx-co        | column of the fornix |
| fx-cr         | column of the fornix, rostral portion |
| fx-c-c      | column of the fornix, caudal portion |
| fx-b         | body of the fornix |
| fx-cr        | crus of the fornix |
| hyhyp        | hypothalamo-hypophyseal tract |
| ilf          | inferior longitudinal fasciculus |
| ithp         | inferior thalamic peduncle |
| ic           | internal capsule |
| aic          | anterior limb of internal capsule |
| pfpf         | prefrontopontine fibers |
| athf         | anterior thalamic radiation |
| gic          | genu of internal capsule |
| cbu-ic       | corticobulbar fibers |
| cre          | corticoreticular fibers |
| pic          | posterior limb of internal capsule |
| lthp         | lenticulothalamic portion |
| csp          | corticospinal fibers |
| fpn          | frontopontine fibers |
| sthr         | superior thalamic radiation |
| cte          | corticotectal fibers |
| cru          | corticorubral fibers |
| relp         | retrolenticular portion |
| pthtr        | posterior thalamic radiation |
| or-ri         | optic radiation (geniculocalcarine tract) |
| pnp          | parietopontine fibers |
| opn          | occipitopontine fibers |
| oco          | occipitocollicular fibers |
| sulp         | sublenticular portion |
| ar-sl         | auditory radiation |
| tepn         | temporopontine fibers |
| imlgp        | internal medullary lamina of globus pallidus |
| imth         | internal medullary lamina of thalamus |
| ils          | lateral longitudinal stria |
| lf           | lenticular fasciculus |
| mp           | mammillary peduncle |
| Abbreviation | Description |
|--------------|-------------|
| mtg          | mammillotegmental tract |
| mtt          | mammillothalamic tract |
| mcht         | medial corticohypothalamic tract |
| mfb          | medial forebrain bundle |
| mls          | medial longitudinal stria |
| or-lp        | Meyer's loop of optic radiation |
| mlf          | middle longitudinal fasciculus |
| npa          | nigropallidal tract |
| nst          | nigrostriate tract |
| off          | occipitofrontal fasciculus |
| offi         | inferior occipitofrontal fasciculus |
| offs         | superior occipitofrontal fasciculus |
| olt          | olfactory tract |
| ost          | olfactory striae |
| lost         | lateral olfactory stria |
| most         | medial olfactory stria |
| ox           | optic chiasm |
| on           | optic nerve |
| or           | optic radiation |
| ot           | optic tract |
| opt          | orbito-polar tract |
| pni          | pallidoniogral tract |
| ptg          | pallidotegmental tract |
| pth          | pallidothalamic tract |
| perf         | perforant path |
| perp         | perpendicular fasciculus |
| ponb         | pontine bundle |
| rthp         | rostral thalamic peduncle |
| sst          | sagittal stratum |
| ssst         | external sagittal stratum |
| ssti         | internal sagittal stratum |
| saf          | short association fibers |
| sr           | somatosensory radiation |
| szt          | stratum zonale of thalamus |
| smt          | stria medullaris of thalamus |
| st           | stria terminalis |
| spa          | striopallidal tract |
| sni          | strionigral tract |
| sth          | striothalamic tract |
| scf          | subcallosal fasciculus |
| sthf         | subthalamic fasciculus |
| sprs         | superficial presubiculbar path |
| slf          | superior longitudinal fasciculus |
| slf-m        | superior longitudinal fasciculus, medial portion |
| slf-i        | superior longitudinal fasciculus, intermediate portion |
| slf-l        | superior longitudinal fasciculus, lateral portion |
| sox          | supraoptic dicussation |
| Abbreviation | Description |
|--------------|-------------|
| tpsl         | temporopulvinar bundle |
| thf          | thalamic fasciculus |
| thpa         | thalamopallidal tract |
| thst         | thalamostriate tract |
| tuin         | tuberoinfundibular path |
| unf          | uncinate fasciculus |
| vamy         | ventral amygdaloidefferent path |
| vof          | vertical occipital fasciculus |
| FV           | ventricles of forebrain |
| LV           | lateral ventricles |
| aLV          | anterior horn of lateral ventricle |
| bLV          | body of lateral ventricle |
| xLV          | atrium of lateral ventricle |
| pLV          | posterior horn of lateral ventricle |
| iLV          | inferior horn of lateral ventricle |
| olr          | olfactory recess |
| 3V           | third ventricle |
| ifr3V        | infundibular recess of 3V |
| por3V        | preoptic recess of 3V |
| pir3V        | pineal recess of 3V |
| spr3V        | suprapineal recess of 3V |
| mmr3V        | mammillary recess of 3V |
| IVF          | interventricular foramen |
| FSS          | surface structures of forebrain |
| CeS          | cerebral sulci |
| PriS         | primary sulci |
| cas          | calcarine fissure (sulcus) |
| cas-r        | rostral (common) portion of calcarine fissure |
| cas-c        | caudal portion of calcarine fissure |
| cas-cs       | superior ramus of caudal calcarine fissure |
| cas-ci       | inferior ramus of caudal calcarine fissure |
| cals         | callosal sulcus |
| cs           | central sulcus |
| cis          | cingulate sulcus |
| mr           | marginal ramus of cingulate sulcus |
| csr          | circular sulcus of Reil |
| csr-u        | upper limiting sulcus |
| csr-l        | lower limiting sulcus |
| cols         | collateral sulcus |
| cols-r       | collateral sulcus, rostral segment (rhinal sulcus, ventral part) |
| cols-c       | collateral sulcus, caudal segment (medial occipitotemporal sulcus) |
| hf           | hippocampal fissure |
| ips          | intraparietal sulcus |
| las          | lateral (sylvian) fissure (sulcus) |
| las-h        | lateral fissure, horizontal (rostral) ramus |
| las-a        | lateral fissure, ascending (middle) ramus |
| las-m        | lateral fissure, main (caudal) ramus |
| Term | Description |
|------|-------------|
| lof | longitudinal fissure |
| ots | occipitotemporal sulcus (lateral occipitotemporal sulcus) |
| ols | olfactory sulcus |
| ors | orbital sulcus |
| ors-m | medial orbital sulcus |
| ors-i | intermediate orbital sulcus |
| ors-p | posterior orbital sulcus |
| ors-l | lateral orbital sulcus |
| ors-t | transverse (arcuate) orbital sulcus |
| pos | parietooccipital fissure (sulcus) |
| pos-le | parietooccipital fissure, lateral extension |
| pocs | postcentral sulcus |
| prcs | precentral sulcus |
| sts | superior temporal sulcus |
| sts-a | superior temporal sulcus, mid-ascending branch |
| tranf | transverse cerebral fissure |
| SecS | secondary sulci |
| aos | anterior occipital sulcus |
| aos-d | anterior occipital sulcus, dorsal ramus |
| aos-v | anterior occipital sulcus, ventral ramus |
| ascS | anterior subcentral sulcus |
| cfts | caudal transverse fusiform sulcus (posterior transverse collateral sulcus) |
| csin | central sulcus of insula |
| ds | diagonal sulcus |
| ers | endorhinal sulcus |
| fimd | fimbriodentate sulcus |
| fms | frontomarginal sulcus |
| fps | frontopolar sulcus |
| fps-d | dorsal frontopolar sulcus |
| fps-v | ventral frontopolar sulcus |
| ifs | inferior frontal sulcus |
| its | inferior temporal sulcus |
| imfs | intermediate frontal sulcus |
| ios | inferior occipital sulcus |
| itos | inferior transverse occipital sulcus |
| ans | angular sulcus |
| mcs | mid-cuneal sulcus |
| mffs | mid-fusiform sulcus (fusiform sulcus) |
| mos | middle (lateral) occipital sulcus |
| mligs | mid-lingual sulcus |
| mprcs | mid-precuneal sulcus |
| lus | lunate sulcus |
| mfs | medial frontal sulcus |
| pacs | paracentral sulcus |
| pacis | paracingulate sulcus |
| phlgs | parahippocampo-ligual sulcus |
| pols | parolfactory sulcus |
| Abbreviation | Definition |
|--------------|------------|
| pols-r       | rostral parolfactory sulcus |
| pols-c       | caudal parolfactory sulcus |
| prin         | precentral sulcus of insula |
| poin         | postcentral sulcus of insula |
| poscs        | posterior subcentral sulcus |
| rs           | rhinal sulcus (dorsal part) |
| rtfs         | rostral transverse fusiform sulcus (posterior transverse collateral sulcus) |
| ros          | rostral sulcus |
| ros-s        | superior rostral sulcus |
| ros-i        | inferior rostral sulcus |
| ss           | semiannular sulcus |
| sps          | subparietal (splenial) sulcus |
| sfs          | superior frontal sulcus |
| spas         | superior parietal sulcus |
| sms          | supramarginal sulcus |
| tps          | temporopolar sulcus |
| tps-m        | medial temporopolar sulcus |
| tps-l        | lateral temporopolar sulcus |
| trps         | transverse parietal sulcus |
| tts          | transverse temporal sulcus |
| atts         | anterior transverse temporal sulcus |
| pttts        | posterior transverse temporal sulcus |
| ims          | intermediate transverse temporal sulcus |
| tttts-le     | lateral extension of transverse temporal sulcus |
| tros         | transverse occipital sulcus |
| trs          | triangular sulcus |
| us           | uncal sulcus |
| CeG          | cerebral gyri and lobules (colors for this group are for online gyral version only) |
| FroL         | frontal lobe |
| PrCG         | precentral gyrus |
| SFG          | superior frontal gyrus |
| MFG          | middle frontal gyrus |
| IFG          | inferior frontal gyrus |
| IFGr         | inferior frontal gyrus, triangular part |
| IFGop        | inferior frontal gyrus, opercular part |
| IFGor        | inferior frontal gyrus, orbital part |
| ReG          | gyrus rectus (straight gyrus) |
| MOrG         | medial orbital gyrus |
| AOrG         | anterior intermediate orbital gyrus |
| PORG         | posterior intermediate orbital gyrus |
| LOrG         | lateral orbital gyrus |
| PClr         | paracentral lobule, rostral part |
| PaCG         | paracingulate gyrus |
| FrO          | frontal operculum |
| OrO          | orbital operculum |
| RoG          | rostral gyrus |
| SROG         | superior rostral gyrus |
TABLE 3. Continued

| Abbreviation | Description |
|--------------|-------------|
| IRoG         | inferior rostral gyrus |
| LOG          | lateral olfactory gyrus |
| FMG          | frontomarginal gyrus |
| FP           | frontal pole |
| ParL         | parietal lobe |
| PoCG         | postcentral gyrus |
| SPL          | supraparietal lobule |
| IPL          | inferior parietal lobule |
| SMG          | supramarginal gyrus |
| AnG          | angular gyrus |
| PrCun        | precuneus |
| PClc         | paracentral lobule, caudal part |
| PaO          | parietal operculum |
| TemL         | temporal lobe |
| STG          | superior temporal gyrus |
| MTG          | middle temporal gyrus |
| ITG          | inferior temporal gyrus |
| FuGt         | occipitotemporal (fusiform) gyrus, temporal part |
| PRG          | perirhinal gyrus (rostral part of FuGt) |
| TTG          | transverse temporal gyrus (Heschl's gyrus) |
| TTGr         | rostral (anterior) transverse temporal gyrus |
| TTGc         | caudal (posterior) transverse temporal gyrus |
| PLT          | planum temporale |
| TP           | temporal pole |
| PRL          | perirhinal lobule |
| PLP          | planum polare |
| OccL         | occipital lobe |
| OP           | occipital pole |
| OPR          | occipitoparietal transition region |
| OTR          | occipitotemporal transition region |
| Cun          | cuneus |
| LiG          | lingual gyrus (medial occipitotemporal gyrus) |
| FuGo         | (lateral) occipitotemporal (fusiform) gyrus, occipital part |
| IOG          | inferior occipital gyrus |
| SOG          | superior occipital gyrus |
| InL          | insular lobe |
| LiG          | long insular gyri |
| SIG          | short insular gyri |
| LimL         | limbic lobe |
| CgG          | cingulate gyrus |
| CgGr         | cingulate gyrus, rostral (anterior) part |
| CgGc         | cingulate gyrus, caudal (posterior) part |
| CgGrS        | cingulate gyrus, retrospleninal part |
| IsCPH        | cingulo-parahippocampal isthmus |
| SCG          | subcallosal gyrus (parolfactory gyrus) |
| PTG          | paraterminal gyrus |
| PHG          | parahippocampal gyrus |
| Abbreviation | Description                                      |
|--------------|--------------------------------------------------|
| APH          | anterior parahippocampal gyrus                   |
| PPH          | posterior parahippocampal gyrus                  |
| UN           | uncus of parahippocampal gyrus                  |
| AG           | gyrus ambiens                                   |
| BG           | band of Giacomini                                |
| ILG          | intralimbic gyrus                                |
| SLG          | semilunar gyrus                                  |
| HiF          | hippocampal gyrus (formation)                   |
| HiH          | head of hippocampus                              |
| HiD          | digitations of hippocampus                       |
| HiB          | body of hippocampus                              |
| HiT          | tail of hippocampus                              |
| FaG          | fasciolar gyrus                                  |
| Retz         | Retzius' gyrus                                   |
| Subx         | subicular complex                                |
| PrPir        | prepiriform region                               |
| APS          | anterior perforated substance                    |
| HaTr         | habenular triangle                               |
| InF          | infundibular stalk                               |
| Li           | limen insula                                     |
| MB           | mammillary body                                  |
| PrN          | preoccipital notch                               |
| TPUJ         | temporopolar uncal junction                      |
| TN           | tentorial notch                                  |
| TC           | tuber cinereum                                   |
| ASFV         | adjoining structures of forebrain ventricles     |
| CalA         | calcar avis                                      |
| ChoLV        | choroid plexus of lateral ventricle              |
| Cho3V        | choroid plexus of 3V                             |
| ChoF         | choroid fissure                                  |
| CoE          | collateral eminence                             |
| CoT          | collateral trigone                               |
| hyths        | hypothalamic sulcus                              |
| InTh         | interthalamic adhesion (massa intermedia)        |
| LaT          | lamina terminalis                                |
| OVLT         | organum vasculosum laminae terminalis           |
| SFO          | subfornical organ                                |
| Pell         | septum pellucidum                                |
| cpell        | cavum septi pellucidi                            |
| vip          | velum interpositum                               |
| fbv          | blood vessels of forebrain                       |
| M            | midbrain (mesencephalon)                         |
| MGM          | gray matter of midbrain                          |
| PTR          | pretectal region                                 |
| PTN          | pretectal nuclear complex                        |
| DPT          | dorsal (posterior/sublentiform) pretectal nucleus |
| MPT          | medial pretectal nucleus                         |
| Acronym | Description |
|---------|-------------|
| NOP    | nucleus of the optic tract (lentiform nucleus) |
| OPT    | olivary pretectal nucleus |
| APT    | anterior (ventral /principal) prectectal division |
| APTc   | anterior prectectal nuclei, compact division |
| APTr   | anterior prectectal nuclei, reticular division |
| AOP    | accessory nuclei of optic tract |
| AOPd   | accessory nuclei of optic tract, dorsal nucleus (dorsal terminal nucleus) |
| AOPI   | accessory nuclei of optic tract, lateral nucleus (lateral terminal nucleus) |
| AOPm   | accessory nuclei of optic tract, medial nucleus (medial terminal nucleus) |
| MTg    | midbrain tegmentum |
| MEN    | efferent nuclei of the cranial nerves in the midbrain |
| EW     | Edinger-Westphal nucleus (accessory oculomotor nucleus) |
| 3N     | oculomotor nucleus |
| 3AM    | anterior median oculomotor nucleus |
| 3CC    | caudal central oculomotor nucleus |
| 3C     | central oculomotor nucleus |
| 3D     | dorsal oculomotor nucleus |
| 3M     | medial oculomotor nucleus |
| 3Vn    | ventral oculomotor nucleus |
| 4N     | trochlear nucleus |
| 4N     | supratrochlear nucleus |
| MAN    | afferent nuclei of the cranial nerves in midbrain |
| Me5    | mesencephalic trigeminal nucleus |
| PAG    | periaqueductal gray substance |
| PAGD   | periaqueductal gray substance, dorsolateral portion |
| PAGdm  | periaqueductal gray substance, dorsomedial division |
| PAGdl  | periaqueductal gray substance, dorsolateral division |
| PAGl   | periaqueductal gray substance, lateral division |
| PAGvl  | periaqueductal gray substance, ventrolateral division |
| PAGpl  | periaqueductal gray substance, pleiogliial division |
| PAGV   | periaqueductal gray substance, ventral portion |
| DRC    | cap of dorsal raphe nucleus |
| Dk     | nucleus of Darkschewitsch |
| PC3    | parvicellular oculomotor nucleus |
| Su3C   | supraoculomotor cap |
| Su3    | supraoculomotor nucleus |
| MRa    | midbrain raphe nuclei |
| DR     | dorsal raphe nucleus |
| DRC    | dorsal raphe nucleus, caudal part |
| DRD    | dorsal raphe nucleus, dorsal part |
| DRI    | dorsal raphe nucleus, interfascicular part |
| DRL    | dorsal raphe nucleus, lateral part |
| DRV    | dorsal raphe nucleus, ventral part |
| DRVL   | dorsal raphe nucleus, ventrolateral part |
| Lin    | linear nucleus of the midbrain |
| CLIZ   | caudal linear nucleus of the raphe |
| CLinAz | caudal linear nucleus of the raphe, azygos part |
| Table 3. Continued |
|-------------------|
| **CLinZ**         | caudal linear nucleus of the raphe, zygos part |
| **RLin**          | rostral linear nucleus of the raphe |
| **MnR**           | median raphe nucleus |
| **PMnR**          | paramedian raphe nucleus |
| **PDR**           | posterodorsal raphe nucleus |
| **Rbd**           | rhabdoid nucleus |
| **isRt**          | isthmic reticular formation |
| **MRF**           | midbrain reticular formation |
| **CnF**           | cuneiform nucleus |
| **PrCnF**         | precuneiform area |
| **U**             | nucleus U |
| **PTg**           | pedunculopontine tegmental nucleus |
| **PTgC**          | pedunculopontine tegmental nucleus, compact part |
| **PTgD**          | pedunculopontine tegmental nucleus, dissipated part |
| **SubCn**         | subcuneiform nucleus |
| **Lth**           | lithoid nucleus |
| **RN**            | red nucleus |
| **RNdm**          | red nucleus, dorsomedial part |
| **RNmc**          | red nucleus, magnocellular part |
| **RNpc**          | red nucleus, parvicellular part |
| **SN**            | substantia nigra |
| **SNC**           | substantia nigra, compact part |
| **SNCd**          | substantia nigra, compact part, dorsal subdivision |
| **SNCm**          | substantia nigra, compact part, medial subdivision |
| **SNCv**          | substantia nigra, compact part, ventral subdivision |
| **SNL**           | substantia nigra, lateral part |
| **SNR**           | substantia nigra, reticular part |
| **VTR**           | ventral tegmental region of midbrain |
| **VTA**           | ventral tegmental area |
| **IF**            | interfascicular nucleus |
| **PBP**           | parabrachial pigmented nucleus |
| **PIF**           | parainterfascicular nucleus |
| **PaN**           | paranigral nucleus |
| **IP**            | interpeduncular nucleus |
| **IPA**           | interpeduncular nucleus, apical subnucleus |
| **IPC**           | interpeduncular nucleus, caudal subnucleus |
| **IPdm**          | interpeduncular nucleus, dorsomedial subnucleus |
| **IPI**           | interpeduncular nucleus, intermediate subnucleus |
| **IPL**           | interpeduncular nucleus, lateral subnucleus |
| **IPr**           | interpeduncular nucleus, rostral subnucleus |
| **XMTg**          | other nuclei in midbrain tegmentum |
| **CeMe**          | central mesencephalic nucleus |
| **CTF**           | central tegmental field |
| **DA8**           | dopamine cells A8 |
| **I3**            | interoculomotor nucleus |
| **InC**           | interstitial nucleus of Cajal |
| **Lt**            | lateral terminal nucleus of accessory optic tract |
| Abbreviation | Description |
|--------------|-------------|
| MCPC         | magnocellular nucleus of the posterior commissure |
| MA3          | medial accessory oculomotor nucleus |
| MiTg         | microcellular tegmental nucleus |
| p1Rt         | p1 reticular formation |
| PaC          | paracollicular tegmentum |
| PaP          | parapeduncular nucleus |
| Pa4          | paratrochlear nucleus |
| PP           | peripeduncular nucleus |
| PDTg         | posterodorsal tegmental nucleus |
| PrC          | precommissural nucleus |
| PrEW         | pre-Edinger-Westphal nucleus |
| RiS          | retroisthmic nucleus |
| RRF          | retrorubral field |
| SubB         | subbrachial nucleus |
| MTc          | midbrain tectum |
| SC           | superior colliculus |
| SCS          | superficial layer of superior colliculus |
| SCSon        | optic nerve layer of superior colliculus |
| SCSg         | superficial gray layer of superior colliculus |
| SCsw         | superficial white layer of superior colliculus |
| SCsz         | zonal layer of superior colliculus |
| SCI          | intermediate layer of the superior colliculus |
| SCIg         | intermediate gray layer of superior colliculus |
| SCiw         | intermediate white layer of superior colliculus |
| SCD          | deep layer of colliculus |
| SCDg         | deep gray layer of superior colliculus |
| SCDw         | deep white layer of superior colliculus |
| BrSC         | nucleus of branchium of superior colliculus |
| IC           | inferior colliculus |
| CxIC         | cortex of inferior colliculus |
| CICd         | dorsal cortex of inferior colliculus |
| CICe         | external cortex of inferior colliculus |
| CIC          | central nucleus of inferior colliculus |
| ICN          | intercollicular nucleus |
| INPC         | interstitial nucleus of posterior commissure |
| MxTZ         | matrix layer of the tectal zone |
| BrIC         | nucleus of the brachium of inferior colliculus |
| PBG          | parabigeminal nucleus |
| Sag          | sagulum nucleus |
| SCO          | subcommissural organ |
| MWM          | white matter of midbrain |
| bic          | brachium of inferior colliculus |
| bsc          | brachium of superior colliculus |
| cttg-m       | central tegmental tract, midbrain portion |
| cpd          | cerebral peduncle (crus cerebri) |
| cpn-m        | corticospinal fibers, midbrain portion |
| fpn-m        | frontal pontine fibers, midbrain portion |
| Abbreviation | Description                                                                 |
|--------------|-----------------------------------------------------------------------------|
| potpn-m      | parieto-occipito-temporal pontine fibers, midbrain portion                  |
| py-m         | pyramidal tract, midbrain portion                                           |
| cbu-m        | corticobulbar tract, midbrain portion                                       |
| cmic         | commissure of inferior colliculus                                           |
| cme          | cortico mesencephalic fibers                                                |
| xrsp         | decussation of rubrospinal tract                                            |
| xscp         | decussation of superior cerebellar peduncle                                 |
| x4           | decussation of trochlear nerve fibers                                       |
| dlf-m        | dorsal longitudinal fasciculus, midbrain portion                           |
| xdtg         | dorsal tegmental decussation                                                |
| dtth-m       | dorsal trigeminothalamic tract, midbrain portion                           |
| fr           | fasciculus retroflexus (habenulo-interpeduncular tract)                    |
| hysp-m       | hypothalamospinal fibers, midbrain portion                                  |
| iptg         | interpedunculotegmental tract                                               |
| issp-m       | interstitiospinal tract, midbrain portion                                   |
| ll-m         | lateral lemniscus, midbrain portion                                        |
| ml-m         | medial lemniscus, midbrain portion                                         |
| mlf-m        | medial longitudinal fasciculus, midbrain portion                           |
| mtg-m        | medial tegmental tract, midbrain portion                                    |
| me5-m        | mesencephalic trigeminal tract, midbrain portion                            |
| poc          | posterior commissure                                                       |
| rubu-m       | rubrobulbar (rubro nuclear) tract, midbrain portion                        |
| rol-m        | rubro-olivary tract, midbrain portion                                       |
| rsp-m        | rubrospinal tract, midbrain portion                                        |
| sl-m         | spinal lemniscus, midbrain portion                                         |
| scp          | superior cerebellar peduncle (brachium conjunctivum)                      |
| cbru         | cerebellorubral tract                                                      |
| cbth         | cerebellothalamic tract                                                    |
| dtth         | dentatothalamic tract                                                      |
| geru         | globose-emboliform-rubral tract                                             |
| rucb         | rubrocerebellar fibers                                                     |
| tcb          | tectocerebellar fibers                                                     |
| vscb-m       | ventral spinocerebellar tract, midbrain portion                            |
| tbu-m        | tectobulbar tract, midbrain portion                                        |
| tol          | tecto-olivary fibers                                                       |
| tpn          | tectopontine tract                                                         |
| tsp-m        | tectospinal tract, midbrain portion                                        |
| xvtg         | ventral tegmental decussation                                               |
| vttm-m       | ventral trigeminothalamic tract, midbrain portion                          |
| wmmtg        | white matter of tegmentum                                                  |
| MV           | ventricle of midbrain                                                      |
| Aq           | cerebral aqueduct                                                          |
| MSS          | surface structures of midbrain                                              |
| fsmv         | frenulum of the superior medullary velum                                   |
| ipf          | interpeduncular fossa                                                      |
| pops         | posterior perforated substance                                              |
| icr          | infracollicular recess                                                      |
| Abbreviation | Description |
|--------------|-------------|
| ocs          | oculomotor sulcus |
| qgb          | quadrigeminal body |
| r3           | root of oculomotor nerve |
| r4           | root of trochlear nerve |
| trill        | trigone of lateral lemniscus (acoustic trigone) |
| H            | hindbrain (rhombencephalon) |
| HGM          | gray matter of the hindbrain |
| Met          | metencephalon |
| CB           | cerebellum |
| CBC          | cerebellar cortex |
| CBV          | cerebellar vermis |
| VeA          | vermis, anterior lobe portion |
| VeAm         | molecular layer of VeA |
| VeAp         | Purkinje cell layer of VeA |
| VeAg         | granular cell layer of VeA |
| VePo         | vermis, posterior lobe portion |
| VePs         | vermis, posterior lobe portion, superior part |
| VePsm        | molecular layer of VePs |
| VePsp        | Purkinje cell layer of VePs |
| VePs g        | granular cell layer of VePs |
| VePi         | vermis, posterior lobe portion, inferior part |
| VePim        | molecular layer of VePi |
| VePig        | Purkinje cell layer of VePi |
| VePig        | granular cell layer of VePi |
| VeF          | vermis, flocculonodular lobe portion (nodulus) |
| VeFm         | molecular layer of VeF |
| VeFp         | Purkinje cell layer of VeF |
| VeFg         | granular cell layer of VeF |
| CBH          | cerebellar hemisphere |
| CBPV         | paravermis of cerebellum |
| PVA          | paravermis, anterior lobe portion |
| PVAm         | molecular layer of PVA |
| PVAp         | Purkinje cell layer of PVA |
| PVAg         | granular cell layer of PVA |
| PVP          | paravermis, posterior lobe portion |
| PVPs         | paravermis, posterior lobe portion, superior part |
| PVPsm        | molecular layer of PVPs |
| PVPsp        | Purkinje cell layer of PVPs |
| PVPsg        | granular cell layer of PVPs |
| PVPi         | paravermis, posterior lobe portion, inferior part |
| PVPim        | molecular layer of PVPi |
| PVPip        | Purkinje cell layer of PVPi |
| PVPig        | granular cell layer of PVPi |
| PVF          | paravermis, flocculonodular lobe portion |
| PVFm         | molecular layer of PVF |
| PVFp         | Purkinje cell layer of PVF |
| PVFg         | granular cell layer of PVF |
| Abbreviation | Description |
|--------------|-------------|
| CBL          | lateral hemisphere of cerebellum |
| CBLA         | lateral hemisphere, anterior lobe portion |
| CBLAm        | molecular layer of CBLA |
| CBLAp        | Purkinje cell layer of CBLA |
| CBLAg        | granular cell layer of CBLA |
| CBLP         | lateral hemisphere, posterior lobe portion |
| CBLPs        | lateral hemisphere, posterior lobe portion, superior part |
| CBLPsms      | molecular layer of CBLPs |
| CBLPsp       | Purkinje cell layer of CBLPs |
| CBLPsg       | granular cell layer of CBLPs |
| CBLPi        | lateral hemisphere, posterior lobe portion, inferior part |
| CBLPim       | molecular layer of CBLPi |
| CBLPip       | Purkinje cell layer of CBLPi |
| CBLPig       | granular cell layer of CBLPi |
| CBLF         | lateral hemisphere, flocculonodular lobe portion |
| CBLFm        | molecular layer of CBLF |
| CBLFp        | Purkinje cell layer of CBLF |
| CBLFg        | granular cell layer of CBLF |
| ChDN         | cerebellar deep nuclei |
| DT           | dentate (lateral) nucleus |
| DTiv         | dentate nucleus, lateroventral part |
| DTmd         | dentate nucleus, mediodorsal part |
| InP          | interpositus (intermediate) nucleus |
| InPM         | medial interpositus (globose) nucleus |
| InPL         | lateral interpositus (emboliform) nucleus |
| Fas          | fastigial (medial) nucleus |
| FasL         | fastigial nucleus, lateral part |
| FasM         | fastigial nucleus, medial part |
| Blcb         | basal interstitial nucleus of cerebellum |
| Pn           | pons |
| PnBa         | basilar part of pons |
| PN           | pontine nucleus |
| PNd          | dorsal nucleus |
| PNdI         | dorsolateral nucleus |
| PNdIm        | dorsomedial nucleus |
| PNI          | lateral nucleus |
| PNm          | median nucleus |
| PNpar        | paramedian nucleus |
| PNPed        | peduncular nucleus |
| RTg          | reticulotegmental nucleus |
| PnTg         | pontine tegmentum |
| PnEN         | efferent nuclei of cranial nerves in pons |
| 6N           | abducens nucleus |
| Acs7         | accessory facial nucleus |
| 7N           | facial nucleus |
| 7D           | facial nucleus, dorsal subnucleus |
| 7VI          | facial nucleus, ventrointermediate subnucleus |
TABLE 3. Continued

| Acronym | Description |
|---------|-------------|
| 7VM     | facial nucleus, ventromedial subnucleus |
| 7SH     | facial nucleus, stylohyoid part |
| 7VL     | facial nucleus, ventrolateral subnucleus |
| Lac     | lacrimal nucleus |
| MoS     | motor nucleus of trigeminal nerve |
| MoSipt  | motor nucleus of trigeminal nerve, lateral pterygoid part |
| MoSma   | motor nucleus of trigeminal nerve, masseter part |
| MoSmp   | motor nucleus of trigeminal nerve, medial pterygoid part |
| MoSmy   | motor nucleus of trigeminal nerve, mylohyoid part |
| MoSte   | motor nucleus of trigeminal nerve, temporalis part |
| SuSV    | superior salivary nucleus |
| PnAN    | afferent nuclei of cranial nerves in pons |
| 8Co     | cochlear nuclei |
| DCo     | dorsal cochlear nucleus |
| GrCo    | granular cell layer of cochlear nuclei |
| VCo     | ventral cochlear nucleus |
| VCoR    | ventral cochlear nucleus, rostral part |
| VCoC    | ventral cochlear nucleus, caudal part |
| Me5-p   | mesencephalic nucleus of trigeminal nerve, pontine part |
| PrS     | principal sensory nucleus of trigeminal nerve |
| PrSdm   | dorsomedial nucleus of Pr5 |
| PrSvl   | ventrolateral nucleus of Pr5 |
| SpSo    | spinal nucleus of trigeminal nerve, oral subnucleus |
| 8Ve-p   | vestibular nuclei in pons |
| LVe     | lateral vestibular nucleus |
| LVeMC   | lateral vestibular nucleus, magnocellular part |
| LVePC   | lateral vestibular nucleus, parvicellular part |
| SuVe    | superior vestibular nucleus |
| VTg     | ventral tegmental nucleus |
| VTgR    | ventral tegmental nucleus, rostral extension |
| VTgl    | ventral tegmental nucleus, infrafascicular part |
| VTgP    | ventral tegmental nucleus, principal part |
| VTgS    | ventral tegmental nucleus, suprafascicular part |
| PnAR    | auditory relay nuclei in pons |
| LLN     | nuclei of lateral lemniscus |
| DLL     | dorsal nucleus of lateral lemniscus |
| ILL     | intermediate nucleus of lateral lemniscus |
| VLL     | ventral nucleus of lateral lemniscus |
| TrZ     | nucleus of trapezoid body |
| TrZI    | lateral nucleus of trapezoid body |
| TrZm    | medial nucleus of trapezoid body |
| TrZv    | ventral nucleus of trapezoid body |
| SOC     | superior olivary complex |
| POI     | periolivary nuclei |
| LPOI    | lateral periolivary nucleus |
| MPOI    | medial periolivary nucleus |
| RO      | retro-olivary cell group |
| Abbreviation | Description                                      |
|--------------|--------------------------------------------------|
| SOI          | superior olivary nucleus                        |
| LSO          | lateral superior olivary nucleus                |
| MSO          | medial superior olive                            |
| SPO          | superior paraolivary nucleus                    |
| PrO          | preolivary nucleus                               |
| PnRa         | raphe pontis nucleus                             |
| DR-p         | dorsal raphe nucleus                             |
| MnR-p        | median raphe nucleus                             |
| PMnRt        | paramedian raphe nucleus, reticular part         |
| PRn          | raphe pontis nucleus                             |
| RIP          | raphe interpositus nucleus                       |
| PnRF         | pontine reticular formation                      |
| PB           | parabrachial nuclei                              |
| LPB          | lateral parabrachial nucleus                     |
| LPBc         | lateral parabrachial nucleus, central part       |
| LPBd         | lateral parabrachial nucleus, dorsal part        |
| LPBe         | lateral parabrachial nucleus, external part      |
| LPBs         | lateral parabrachial nucleus, superior part      |
| MPB          | medial parabrachial nucleus                      |
| MPBe         | medial parabrachial nucleus, external part       |
| MPBm         | medial parabrachial nucleus, medial part         |
| SPP          | subpeduncular pigmented nucleus                  |
| SPB          | subparabrachial nucleus                          |
| PnRt         | reticular nuclei of pons                         |
| PnC          | pontine reticular nucleus, caudal part           |
| PnO          | pontine reticular nucleus, oral part             |
| PLN          | paralemniscal nucleus                            |
| PMn          | paramedian reticular nucleus                     |
| RtTg         | reticulotegmental nucleus                        |
| RtTgD        | reticulotegmental nucleus, dorsal part           |
| PnNA         | group of noradrenergic neurons in pons            |
| NC           | nucleus coeruleus                                |
| SubC         | subcoeruleus nucleus                              |
| SubCd        | subcoeruleus nucleus, dorsal part                |
| SubCv        | subcoeruleus nucleus, ventral part               |
| XpNtG        | other nuclei in pontine tegmentum                |
| Acs5         | accessory trigeminal nucleus                      |
| AlnS         | alar interstitial nucleus                         |
| B9           | B9 serotonin cells                               |
| Bar          | Barrington's nucleus                              |
| PnCG         | central gray of pons                              |
| CAT          | central nucleus of acoustic tract                |
| DTg          | dorsal tegmental nucleus                          |
| DTgC         | dorsal tegmental nucleus, central part           |
| DTgP         | dorsal tegmental nucleus, pericentral part       |
| DMTg         | dorsomedial tegmental area                        |
| PnE          | ependyma and subependymal layers of pons          |
| Lower-case Code | Anatomical Structure |
|-----------------|----------------------|
| EpC             | epicoeruleus nucleus  |
| PnG             | pontine gamma nucleus |
| IIMLF           | intermediate interstitial nucleus of medial longitudinal fasciculus |
| IMLF            | interstitial nucleus of medial longitudinal fasciculus |
| IS              | intertrigeminal nucleus |
| JxO             | juxtaolivary nucleus  |
| KF              | Koelliker-Fuse nucleus |
| LDTg            | laterodorsal tegmental nucleus |
| LDTgD           | laterodorsal tegmental nucleus, dorsal part |
| LDTgV           | laterodorsal tegmental nucleus, ventral part |
| NI              | nucleus incertus |
| K               | nucleus K |
| L               | nucleus L |
| Pa6             | paraabducens nucleus |
| PCuN            | pericuneate nuclei |
| LPCu            | lateral pericuneate nucleus |
| MPCu            | medial pericuneate nucleus |
| PF7             | perifacial zone |
| PnBi            | pontobulbar nucleus, inferior part |
| P5              | peritrigeminal zone |
| R7              | retrofacial nucleus |
| RTz             | retrotrapezoid nucleus |
| 5N              | trigeminal nuclei |
| VLTg            | ventrolateral tegmental nucleus |
| SGe             | supragenual nucleus |
| Mo              | myelencephalon (medulla oblongata) |
| MoPy            | pyramidal part of medulla oblongata |
| Ar              | arcuate nucleus of medulla oblongata |
| Ct              | conterminal nucleus |
| MoTg            | tegmentum of medulla oblongata |
| MoEN            | efferent nuclei of cranial nerves in the medulla oblongata |
| Amb             | ambiguus nucleus |
| AmbC            | ambiguus nucleus, compact part |
| AmbL            | ambiguus nucleus, loose part |
| AmbSC           | ambiguus nucleus, semicompact part |
| 12N             | hypoglossal nucleus |
| 12GH            | hypoglossal nucleus, geniohyoid part |
| 12L             | hypoglossal nucleus, lateral part |
| 12M             | hypoglossal nucleus, medial part |
| 12V             | hypoglossal nucleus, ventral part |
| InSV            | inferior salivatory nucleus |
| 10N             | dorsal motor nucleus of the vagus (vagal nucleus) |
| 10Cal           | dorsal motor nucleus of vagus, caudointermediate part |
| 10Cel           | dorsal motor nucleus of vagus, centrointermediate part |
| 10DI            | dorsal motor nucleus of vagus, dorsointermediate part |
| 10DR            | dorsal motor nucleus of vagus, dorsorostral part |
| 10F             | dorsal motor nucleus of vagus, medial fringe |
| Abbreviation | Description                                                                 |
|--------------|-----------------------------------------------------------------------------|
| 10VI         | dorsal motor nucleus of vagus, ventrointermediate part                      |
| 10VR         | dorsal motor nucleus of the vagus, ventroorostral part                      |
| MoAN         | afferent nuclei of cranial nerves in medulla oblongata                      |
| Sol          | solitary nucleus                                                            |
| SolC         | solitary nucleus, commissural part                                          |
| SolD         | solitary nucleus, dorsal part                                               |
| SolDL        | solitary nucleus, dorsolateral part                                         |
| SolG         | solitary nucleus, gelatinous part                                           |
| SolIM        | solitary nucleus, intermediate part                                         |
| SolI         | solitary nucleus, interstitial part                                         |
| SolM         | solitary nucleus, medial part                                               |
| SolPaC       | solitary nucleus, paracommissural part                                       |
| SolV         | solitary nucleus, ventral part                                              |
| SolVL        | solitary nucleus, ventrolateral part                                        |
| SSol         | subsolitary nucleus                                                         |
| PSol         | parasolitary nucleus                                                        |
| Sp5          | spinal trigeminal nucleus                                                   |
| Sp5C         | spinal trigeminal nucleus, caudal part                                       |
| DM5          | dorsomedial spinal trigeminal nucleus                                       |
| Sp5ip        | spinal trigeminal nucleus, interpolar part                                   |
| 8Ve          | vestibular nuclei in medulla                                                |
| I8           | interstitial nucleus of the vestibulocochlear nerve                          |
| MVe          | medial vestibular nucleus                                                   |
| MVeMC        | medial vestibular nucleus, magnocellular part                               |
| MVePC        | medial vestibular nucleus, parvcellular part                                |
| EVe          | nucleus of origin of vestibular efferents of vestibular nerve               |
| SpVe         | spinal (inferior) vestibular nucleus                                        |
| PaVe         | paravestibular nucleus                                                      |
| MoSR         | sensory relay nuclei in medulla oblongata                                    |
| ECu          | external (accessory/lateral) cuneate nucleus                                |
| Cu           | cuneate nucleus                                                             |
| CuR          | cuneate nucleus, rotundus part                                              |
| CuT          | cuneate nucleus, triangular part                                            |
| Gr           | gracile nucleus                                                             |
| GrC          | gracile nucleus, central part                                               |
| GrR          | gracile nucleus, rostral part (shell)                                       |
| PrCbn        | precerebellar nuclei                                                        |
| Crb          | cribriform nucleus                                                           |
| DPMn         | dorsal paramedian nucleus                                                   |
| CDPMn        | caudal dorsal paramedian nucleus                                            |
| ODPMn        | rostral (oral) dorsal paramedian nucleus                                    |
| IO           | inferior olive                                                              |
| IODM         | inferior olive, dorsomedial cell group                                       |
| IOBe         | inferior olive, beta nucleus                                                |
| IOD          | inferior olive, dorsal nucleus                                              |
| IODC         | inferior olive, dorsal nucleus, caudal part                                 |
| IOM          | inferior olive, medial nucleus                                              |
| Abbreviation | Description |
|--------------|-------------|
| IOK          | Cap of Kooy of medial nucleus |
| IOA          | subnucleus A of medial nucleus |
| IOB          | subnucleus B of medial nucleus |
| IOC          | subnucleus C of medial nucleus |
| IOPr         | inferior olive, principal nucleus |
| IOVL         | ventrolateral outgrowth of inferior olive |
| InM          | intercalated nucleus of medulla |
| IPo          | interpositus nucleus |
| PnbN         | pontobulbar nucleus |
| PrH          | prepositus hypoglossal nucleus |
| MoRF         | medullary reticular formation |
| DRt          | dorsal reticular nucleus |
| IRt          | intermediate reticular nucleus |
| CVL          | caudoventrolateral reticular nucleus |
| NA/A         | noradrenaline/adrenaline cell group 1 |
| RVRG         | rostral ventral respiratory cell group |
| RVL          | rostroventrolateral reticular nucleus of hindbrain |
| GiRt         | gigantocellular reticular nuclei |
| GiRtA        | alpha gigantocellular reticular nucleus |
| LPGi         | lateral paragigantocellular nucleus |
| PGI          | paragigantocellular nucleus |
| APGi         | alpha part of paragigantocellular nucleus |
| DPGi         | dorsal paragigantocellular nucleus |
| GiRtV        | ventral gigantocellular reticular nucleus |
| LMRt         | lateral reticular nuclei |
| LRT          | lateral reticular nucleus (principal part) |
| LRTMC        | lateral reticular nucleus, magnocellular part |
| LRTC         | lateral reticular nucleus, parvocellular part |
| LRTSS        | lateral reticular nucleus, subtrigeminal part |
| Li           | linear nucleus of hindbrain |
| MdD          | medullary reticular nucleus, dorsal part (ventral reticular nucleus) |
| MdV          | medullary reticular nucleus, ventral part (medial reticular nucleus) |
| PCrt         | parvocellular reticular nucleus |
| PCrta        | alpha division of parvocellular reticular nucleus |
| MoRa         | raphe nuclei in medulla oblongata |
| RMg          | raphe magnus nucleus |
| ROb          | raphe obscurus nucleus |
| RPa          | raphe pallidus nucleus |
| NPRa         | nucleus paraparaphales |
| XMoTg        | other nuclei in medullary tegmentum |
| Au           | austral nucleus |
| Bi           | basal interstitial nucleus |
| Bo           | Bötzinger complex |
| CGL          | central glial substance |
| MoCG         | central gray of medulla oblongata |
| DPO          | dorsal periolivary nucleus |
| MoE          | ependyma and subependymal layers of the medulla |
| Abbreviation | Description                                           |
|--------------|--------------------------------------------------------|
| EL           | endolemniscal nucleus                                  |
| EF           | epifascicular nucleus                                  |
| IF12         | interfascricular hypoglossal nucleus                   |
| IB           | internal basal nucleus                                 |
| Nt           | notocuneate nucleus                                    |
| Z            | nucleus Z (posterodorsal subnucleus)                  |
| Y            | nucleus Y                                             |
| X            | nucleus X (preaccessory cuneate nucleus)              |
| Ro           | nucleus of Roller                                     |
| Pa5          | paratrigeminal nucleus                                 |
| PeCu         | pericuneate nucleus                                    |
| PeS          | peritrigeminal nucleus                                 |
| PrBo         | pre-Bötzinger complex                                  |
| RAMb         | retroambigous nucleus                                  |
| SSFp         | spinal accessory (supraspinal) nucleus                 |
| SuL          | supralemniscal nucleus                                 |
| HWM          | white matter of hindbrain                             |
| AMI          | amiculum of the olive                                  |
| AF7          | ascending fibers of the facial nerve                  |
| CTG          | central tegmental tract                                |
| CPN          | cortico-pontine fibers, pontine part                   |
| CUF          | cuneate fasciculus                                    |
| XMl          | decussation of medial lemniscus                        |
| Das          | dorsal acoustic stria                                  |
| Def          | dorsal external fibers                                 |
| Dlf-H        | dorsal longitudinal fasciculus                         |
| Dtgth        | dorsal trigeminothalamic tract                         |
| EAF          | external arcuate fibers                                |
| G7           | genu of the facial nerve                               |
| Gr           | gracile fasciculus                                     |
| HIO          | hilus of the inferior olive                            |
| Hypsp        | hypothalamospinal tract                                |
| ICP          | inferior cerebellar peduncle                           |
| RSF          | restiform body                                         |
| CBRF         | cerebelloreticular fibers                              |
| CBVF         | cerebellovestibular fibers                             |
| CUCB         | cuneocerebellar tract                                  |
| DSC          | dorsal spinocerebellar tract                           |
| OCB          | olivocerebellar tract                                  |
| RCBTM        | reticulocerebellar tract, medullary division           |
| SCT          | spinocerebellar tract                                  |
| JX           | juxta-vestiform body                                   |
| FASR         | fastigial reticular tract                              |
| FASV         | fastigial vestibular tract                             |
| TGCB         | trigemino-cerebellar tract                             |
| VECB         | vestibulocerebellar tract                              |
| IAS          | intermediate acoustic stria                            |
| Abbreviation | Description |
|--------------|-------------|
| iaf          | internal arcuate fibers |
| issp         | interstitiospinal tract |
| lbrs         | lateral bulboreticulospinal tract |
| lcs          | lateral corticospinal tract |
| ll           | lateral lemniscus |
| lvs          | lateral vestibulospinal tract |
| lfpn         | longitudinal fasciculus of the pons |
| ml           | medial lemniscus |
| mlf          | medial longitudinal fasciculus |
| metg         | medial tegmental tract |
| mvet         | medial vestibulospinal tract |
| me5          | mesencephalic trigeminal tract |
| mcp          | middle cerebellar peduncle |
| pncb         | pontocerebellar tract, pontine division |
| olcob        | olivocochlear bundle |
| xpy          | pyramidal decussation |
| py           | pyramidal tract |
| cbu-h        | corticobulbar tract |
| cre-h        | corticoreticular tract |
| csp-h        | corticospinal tract |
| rsp          | raphespinal tract |
| lrsp         | lateral raphespinal tract |
| vrsp         | ventral raphespinal tract |
| rbb          | rubrobulbar tract |
| rol          | rubro-olivary tract |
| rusp         | rubrospinal tract |
| sol          | solitary tract |
| slih         | spinal lemniscus in hindbrain |
| spb          | spinobulbar tract |
| sphy         | spinohypothalamic tract |
| spme         | spinomesencephalic tract |
| spre         | spinoreticular tract |
| sptth        | spinothalamic tract |
| spve         | spinovestibular tract |
| tbu          | tectobulbar tract |
| sp5          | spinal trigeminal tract |
| spol         | spino-olivary tract |
| sm4V         | stria medulaires of the fourth ventricle |
| tsp          | tectospinal tract |
| tfp          | transverse fibers of pons |
| tz           | trapezoid body |
| tri5         | trigeminothalamic tract |
| ubcb         | uncinate (hooked) bundle of cerebellum |
| vcsd         | ventral corticospinal tract |
| vexf         | ventral external fibers |
| vresp        | ventral reticulospinal tract |
| Abbreviation | Description                                      |
|-------------|---------------------------------------------------|
| vscb        | ventral spinocerebellar tract                     |
| vtg         | ventral tegmental tract                           |
| vth         | ventral trigeminotralamic tract                   |
| veme        | vestibulomesencephalic tract                      |
| HV          | ventricles of hindbrain                           |
| 4V          | fourth ventricle                                  |
| 4Vro        | roof of fourth ventricle                          |
| 4Vrf        | lateral recess of fourth ventricle                |
| 4VfI        | floor of fourth ventricle (rhomobd fossa)        |
| cec         | central canal of medulla oblongata                |
| HSS         | surface structures of hindbrain                   |
| CbSS        | surface structures of cerebellum                 |
| cbf         | cerebellar fissures                              |
| prcf        | precentral (postlingual) fissure                  |
| pocf        | postcentral (preculminate) fissure                |
| icf         | intraculminate fissure                           |
| prif        | primary (anterior superior) fissure               |
| psf         | posterior superior (postclival) fissure           |
| hof         | horizontal (intercrural) fissure                  |
| apf         | ansoparamedian fissure                           |
| prpy        | prepyramidal (prebiventral) fissure              |
| ibif        | intrabiventral fissure                           |
| popy        | secondary (post pyramidal) fissure               |
| polf        | posterolateral (postnodular) fissure             |
| CBLl        | cerebellar lobes and lobules                     |
| ACB         | anterior lobe                                     |
| Cbl         | lobule I (lingula)                                |
| CblI        | lobule II (central lobule and wing, anterior part)|
| CblII       | lobule III (central lobule and wing, posterior part)| |
| CblIV       | lobule IV (culmen and quadrangular lobule, anterior part) |
| CblV        | lobule V (culmen and quadrangular lobule, posterior part) |
| PCB         | posterior lobe                                    |
| CblVI       | lobule VI (declive and simplex lobule)           |
| CblVIIa1    | lobule VIIA/crus I (folium and superior semilunar lobule) |
| CblVIIa2    | lobule VIIAt/crus II (tuber and inferior semilunar lobule) |
| CblVIIb     | lobule VIIB (gracile lobule)                      |
| CblVIIIa    | lobule VIII A (pyramid and biventral lobule, anterior part) |
| CblVIIIb    | lobule VIII B (pyramid and biventral lobule, posterior part) |
| CblX        | lobule IX (uvula and tonsil)                      |
| FNCb        | flocculonodular lobe                              |
| Cbx         | lobule X (nodulus and flocculus)                 |
| PnSS        | surface structures of pons                        |
| bas         | basilar sulcus                                    |
| IsRh        | isthmus of rhombencephalon                        |
| pbr         | parabrachial recess                               |
| pmed        | pontomedullary sulcus                             |
| pmes        | pontomesencephalic sulcus                         |
| Term   | Description                                      |
|--------|--------------------------------------------------|
| r6     | root of abducens nerve                           |
| r7     | root of facial nerve                             |
| r7m    | motor root of facial nerve                       |
| r7in   | root of intermediate nerve                       |
| r5     | root of trigeminal nerve                         |
| r5m    | motor root of trigeminal nerve                   |
| r5s    | sensory root of trigeminal nerve                 |
| r8     | root of vestibulocochlear nerve                  |
| r8co   | cochlear root of vestibulocochlear nerve         |
| r8ve   | vestibular root of vestibulocochlear nerve       |
| rmv    | rostral (anterior) medullary velum               |
| AS4V   | adjoining structures of fourth ventricle        |
| AP     | area postrema                                    |
| Cho4V  | choroid plexus of the fourth ventricle           |
| FaC    | facial colliculus                                |
| FovI   | fovea inferior                                   |
| FovS   | fovea superior                                   |
| FnS    | funiculus separans                               |
| 12Tr   | hypoglossal trigone                              |
| la4V   | lateral aperture (foramen of Luschka)            |
| LC     | locus coerulesus                                 |
| MEM    | medial eminence                                  |
| ma4V   | median aperture (foramen of Magendie)            |
| MSul   | median sulcus                                    |
| Obx    | obex                                             |
| SulL   | sulcus limitans                                  |
| Tae    | taenia cinerea                                   |
| 10Tr   | vagal trigone                                    |
| MOSS   | surface structures of medulla                    |
| alms   | anterolateral medullary sulcus                   |
| pros   | preolivary sulcus                                |
| cutu   | cuneate tubercle                                 |
| dmms   | dorsal (posterior) median medullary sulcus       |
| fce    | foramen caecum                                   |
| grtu   | gracile tubercle (clava)                         |
| imv    | inferior (caudal) medullary velum                |
| dims   | dorsal intermediate medullary sulcus             |
| dlims  | dorsal lateral medullary sulcus                  |
| posos  | postolivary sulcus                               |
| r11    | root of accessory nerve                          |
| r11cr  | cranial root of accessory nerve                  |
| r11sp  | spinal root of accessory nerve                   |
| r12    | root of hypoglossal nerve                        |
| r9     | root of glossopharyngeal nerve                   |
| r10    | root of vagus nerve                              |
| vmms   | ventral (anterior) median medullary sulcus       |
| SpC    | spinal cord                                      |
Figure 16. Anteroposterior position of the 106 annotated plates shown in Figure 17. Major macroscopic landmarks (sulci and gyri) on the medial aspect of the left hemisphere are indicated (flipped to show the plate levels (plates 1–106) in an anterior-to-posterior order). General locations of slabs 1–8 were also marked at the top. Note that in slabs 4–7, only the alternative plates were indicated, to avoid busy lines. For abbreviations see Table 3. Scale bar = 2 cm.

Figure 17. Human brain atlas plates. 106 plates with matching histological sections are displayed in anterior-to-posterior (A-P) order. The matching histological images include 50 Nissl-stained, and 50 NFP- and 6 PV-immunostained sections. The 106 plate images, corresponding to the A-P positions delineated in Figure 16, combine the cortical annotation of modified Brodmann areas and traditional gyri and sulci. At each level, a color-coded atlas plate ("a" series; 1a–106a) and a histological image ("b" series; 1b–106b) are presented. The inset diagram at the top right corner of each atlas plate shows the A-P position (red line) of that plate on a schematic representation of the whole hemisphere based on MRI. The green lettering along the cortical surface indicates cortical sulci (lower case, often with black arrowheads) and gyri (upper case), which were generally defined by adjacent sulci. Modified Brodmann areas were labeled within the cortical gray matter with differential color coding. In plates containing cerebellar cortex, alternative plates were annotated for three cerebellar cortical zones (vermis, paravermis, and lateral hemisphere) and 10 lobules (lobules I–X), respectively. Other subcortical structures were also labeled with differential color coding. The general locations of most white matter tracts are indicated by a circled "W". Fiber tracts with clear boundaries, such as ac, mtt, ot, sste/or, fx, fr, scp, py, and ml, were outlined by black lines without color code (white). The parcellation and subdivisions of different brain regions as well as the parent–daughter relationship and abbreviation of each structure are detailed in Table 3. Note that two separate versions of this atlas for modified Brodmann areas and traditional gyri and sulci, respectively, are available in the online version of this atlas (www.brainspan.org or http://brainspan.org/static/atlas). For abbreviations see Table 3. Scale bar = 5 mm (at levels 1b–106b).

| SGM  | laminar I of spinal cord |
|------|----------------------------|
| Spl  | laminar II of spinal cord |
| SpII | laminar III and IV of spinal cord |
| SpIV | laminar V and VI of spinal cord |
| SpVII| laminar VII of spinal cord  |
| CeCv | central cervical nucleus of spinal cord |
| SpVIII| laminar VIII of spinal cord |
| SpIX | laminar IX of spinal cord |
| SpX  | laminar X of spinal cord |
| SWM  | white matter of spinal cord |
| dfs  | dorsal fasciculus of spinal cord |
| Ifs  | lateral fasciculus of spinal cord |
| polt | posterior lateral tract of spinal cord |
| vfs  | ventral fasciculus of spinal cord |
| SV   | ventricle of spinal cord |
| cces | central canal and ependyma of spinal cord |
| SSS  | surface structures of spinal cord |
| rsn  | roots of spinal nerves |
| vmss | ventral (anterior) median spinal sulcus |
Figure 17. Level 1a (01_111)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 1b (NFP (SMI-32))
Figure 17. Level 2a (01_179)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 2b (Nissl)
Figure 17. Level 3a (01_247)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 3b (NFP (SMI-32))
Figure 17. Level 4a (01_307)
Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 4b (Nissl)
Figure 17. Level 5a (02_111)

Link to online high resolution atlas plate

Link to online high resolution atlas plate (Nissl)
Figure 17. Level 5b (NFP (SMI-32))
Figure 17. Level 6a (02_111)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 6b (NFP (SMI-32))
Figure 17. Level 7a (02_175)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 7b (Nissl)
Figure 17. Level 8a (02_219)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 8b (NFP (SMI-32))
Figure 17. Level 9a (02_231)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 9b (NFP (SMI-32))
Figure 17. Level 10a (02_295)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 10b (Nissl)
Figure 17. Level 11a (02_335)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 11b (NFP (SMI-32))
Figure 17. Level 12a (02_359)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 13a (02_407)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 13b (Nissl)
Figure 17. Level 14a (03_031)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 14b (Parvalbumin)
Figure 17. Level 15a (03_095)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 15b (Nissl)
Figure 17. Level 16b (Nissl)
Figure 17. Level 17a (03_227)

Link to online high resolution atlas plate
Link to online high resolution atlas plate (Nissl)
Figure 17. Level 17b (Nissl)
Figure 17. Level 18a (03_291)

Link to online high resolution atlas plate

Link to online high resolution atlas plate (Nissl)
Figure 17. Level 18b (Nissl)
Figure 17. Level 19a (04_035)

Link to online high resolution atlas plate

Link to online high resolution atlas plate (Nissl)
Figure 17. Level 19b (Nissl)
Figure 17. Level 20a (04_051)

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Figure 17. Level 20b (NFP (SMI-32))
Figure 17. Level 21a (04_059)

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Figure 17. Level 21b (Nissl)
Figure 17. Level 22a (04_083)

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Figure 17. Level 22b (Nissl)
Figure 17. Level 23a (04_095)

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Figure 17. Level 23b (NFP (SMI-32))
Figure 17. Level 24a (04_115)

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Figure 17. Level 24b (Nissl)
Figure 17. Level 25a (04_135)

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Figure 17. Level 25b (NFP (SMI-32))
Figure 17. Level 26a (04_147)

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Figure 17. Level 26b (Nissl)
Figure 17. Level 27a (04_167)

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Figure 17. Level 27b (NFP (SMI-32))
Figure 17. Level 28a (04_179)
Figure 17. Level 28b (Nissl)
Figure 17. Level 29a (04_195)

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Figure 17. Level 29b (NFP (SMI-32))
Figure 17. Level 30a (04_207)

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Figure 17. Level 30b (Nissl)
Figure 17. Level 31a (04_215)

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Figure 17. Level 31b (NFP (SMI-32))
Figure 17. Level 32a (04_231)

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Figure 17. Level 32b (Nissl)
Figure 17. Level 33a (04_239)

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Figure 17. Level 33b (Nissl)
Figure 17. Level 34a (04_251)

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Figure 17. Level 34b (Nissl)
Figure 17. Level 35a (04_259)

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Figure 17. Level 35b (NFP (SMI-32))
Figure 17. Level 36a (04_267)

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Figure 17. Level 36b (Nissl)
Figure 17. Level 37a (04_279)

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Figure 17. Level 37b (NFP (SMI-32))
Figure 17. Level 38a (04_291)

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Figure 17. Level 38b (Nissl)
Figure 17. Level 39a (04_307)
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Figure 17. Level 40a (04_315)

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Figure 17. Level 40b (Nissl)
Figure 17. Level 41a (04_327)

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Figure 17. Level 41b (NFP (SMI-32))
Figure 17. Level 42a (04_335)

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Figure 17. Level 42b (Nissls)
Figure 17. Level 43a (05_031)

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Figure 17. Level 43b (Nissl)
Figure 17. Level 44a (05_047)
Figure 17. Level 44b (Nissl)
Figure 17. Level 45a (05_063)

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Figure 17. Level 45b (NFP (SMI-32))
Figure 17. Level 46a (05_079)

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Figure 17. Level 46b (NFP (SMI-32))
Figure 17. Level 47a (05_091)

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Figure 17. Level 47b (NFP (SMI-32))
Figure 17. Level 48a (05_103)

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Figure 17. Level 48b (Nissl)
Figure 17. Level 49a (05_123)

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Figure 17. Level 49b (Nissl)
Figure 17. Level 50a (05_135)

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Figure 17. Level 50b (NFP (SMI-32))
Figure 17. Level 51a (05_147)

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Figure 17. Level 51b (Nissl)
Figure 17. Level 52a (05_159)

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Figure 17. Level 52b (Nissl)
Figure 17. Level 53a (05_171)
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Figure 17. Level 53b (Nissl)
Figure 17. Level 54a (05_187)

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Figure 17. Level 54b (NFP (SMI-32))
Figure 17. Level 55a (05_203)

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Figure 17. Level 56a (05_223)

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Figure 17. Level 58b (NFP (SMI-32))
Figure 17. Level 59a (05_275)

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Figure 17. Level 60a (05_287)

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Figure 17. Level 60b (NFP (SMI-32))
Figure 17. Level 61a (05_303)

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Figure 17. Level 61b (Parvalbumin)
Figure 17. Level 62a (05_311)

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Figure 17. Level 62b (NFP (SMI-32))
Figure 17. Level 63a (05_323)

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Figure 17. Level 63b (Nissl)
Figure 17. Level 64a (06_035)

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Figure 17. Level 64b (Parvalbumin)
Figure 17. Level 65a (05_047)

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Figure 17. Level 66a (06_063)

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Figure 17. Level 66b (NFP (SMI-32))
Figure 17. Level 67a (06_083)

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Figure 17. Level 68a (06_095)

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Figure 17. Level 68b (NFP (SMI-32))
Figure 17. Level 69a (06_107)
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Figure 17. Level 69b (Parvalbumin)
Figure 17. Level 70a (06_119)

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Figure 17. Level 70b (NFP (SMI-32))
Figure 17. Level 71a (06_131)

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Figure 17. Level 71b (Nissl)
Figure 17. Level 72a (06_147)

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Figure 17. Level 72b (Parvalbumin)
Figure 17. Level 73a (06_159)

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Figure 17. Level 73b (NFP (SMI-32))
Figure 17. Level 74b (NFP (SMI-32))
Figure 17. Level 75a (06_195)

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Figure 17. Level 75b (Nissl)
Figure 17. Level 76a (06_207)

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Figure 17. Level 76b (NFP (SMI-32))
Figure 17. Level 77a (06_223)

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Figure 17. Level 77b (Parvalbumin)
Figure 17. Level 78b (Nissl)
Figure 17. Level 79a (06_255)

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Figure 17. Level 79b (NFP (SMI-32))
Figure 17. Level 80a (06_271)

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Figure 17. Level 80b (NFP (SMI-32))
Figure 17. Level 81a (06_291)

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Figure 17. Level 81b (NFP (SMI-32))
Figure 17. Level 82a (06_299)

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Figure 17. Level 82b (Nissl)
Figure 17. Level 83a (07_027)

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Figure 17. Level 83b (Nissl)
Figure 17. Level 84a (07_043)

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Figure 17. Level 85a (07_059)

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Figure 17. Level 85b (NFP (SMI-32))
Figure 17. Level 86a (07_075)

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Figure 17. Level 86b (Nissl)
Figure 17. Level 87a (07_091)

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Figure 17. Level 88a (07_111)

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Figure 17. Level 88b (NFP (SMI-32))
Figure 17. Level 89a (07_123)

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Figure 17. Level 90a (07_147)

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Figure 17. Level 90b (NFP (SMI-32))
Figure 17. Level 91a (07_163)

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Figure 17. Level 91b (NFP (SMI-32))
Figure 17. Level 92a (07_171)

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Figure 17. Level 92b (Nissl)
Figure 17. Level 93a (07_191)

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Figure 17. Level 93b (NFP (SMI-32))
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Figure 17. Level 96b (NFP (SMI-32))
Figure 17. Level 97a (07_251)

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Figure 17. Level 97b (Nissl)
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Figure 17. Level 99a (07_287)

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Figure 17. Level 100b (Nissl)
Figure 17. Level 101a (07_315)

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Figure 17. Level 101b (NFP (SMI-32))
Figure 17. Level 102a (08_039)

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Figure 17. Level 102b (Nissl)
Figure 17. Level 103a (08_103)

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Figure 17. Level 103b (NFP (SMI-32))
Figure 17. Level 104a (08_167)

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Figure 17. Level 104b (Nissl)
Figure 17. Level 105a (08_231)

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Figure 17. Level 105b (NFP (SMI-32))
Figure 17. Level 106a (08_291)

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Link to online high resolution atlas plate (Nissl)
Figure 17. Level 106b (Nissl)
Figure 19. MRI and DWI plates from the same brain. Left column: Seventy-six sequential 7T MRI slices from the same left hemisphere as the atlas shown in Figure 17 were annotated according to the atlas plates in Figure 17. The interval between each slice is 2 mm. The MRI images were annotated for easily predicted and/or identified structures through correspondence to the annotated histological atlas. Several clearly delineated fiber tracts are annotated as well, including the optic radiation ("or" at levels 42–69) and somatosensory radiation ("sr" at levels 38–46). For abbreviations see Table 3. Right column: Top panel shows colorized fractional anisotropy (FA) maps of the corresponding plane of section in the DWI dataset, representing the primary eigenvectors of the diffusion tensor data overlaid on the FA map. Bottom panel shows tractography images created in TrackVis showing all tracts passing through the represented plane of section (90% of tracts omitted with only tracts longer than 20 mm displayed). Scale bars = 5 mm.

Figure 18. Gross anatomy of the left hemisphere and anteroposterior position of the 76 annotated MRI images shown in Figure 19. Main macroscopic landmarks (sulci and gyri) on dorsal (A), lateral (B), and ventral (C) aspects of the left hemisphere are indicated. The A-P locations (levels 1–76) of the 76 MRI images are marked with black lines 1–76 in B. * and # indicate two corresponding regions. For abbreviations see Table 3. Scale bar = 2 cm in A (applies to A–C).
Figure 18.
Figure 19. Level 10

Adult human brain atlas
Figure 19. Level 16 Adult human brain atlas
Figure 19. Level 18

Adult human brain atlas
Figure 19. Level 19
Figure 19. Level 20

Adult human brain atlas
Figure 19. Level 24

Adult human brain atlas
Figure 19. Level 25
Figure 19. Level 28
Adult human brain atlas
Figure 19. Level 30

Adult human brain atlas
Figure 19, Level 32

Adult human brain atlas
Figure 19. Level 34

Adult human brain atlas
Figure 19. Level 36

Adult human brain atlas
Figure 19. Level 37
Figure 19. Level 51
Figure 19. Level 54

Adult human brain atlas
Adult human brain atlas
Figure 19. Adult human brain atlas
Figure 19. Level 64

Adult human brain atlas
Figure 19. Level 66

Adult human brain atlas
Figure 19. Level 74

Adult human brain atlas
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