

Defined Vocabulary for Nervous System Structural Connectivity Description

This is the defined vocabulary for the *Foundational Model of Connectivity*, originally published as Supporting Text in Swanson, L.W. & Bota, M. (2010) Foundational model of nervous system structural connectivity with a schema for wiring diagrams, connectome, and basic plan architecture. *Proceedings of the National Academy of Sciences USA* **107**:20610-20617. It provides standard terms (concepts) for describing the organization of neural networks in all animals at all levels of resolution, and it complements the accompanying *Defined Vocabulary for Nervous System Network Analysis*. Standard terms are **bolded**. There is a bibliography after the lexicon, followed by text describing construction of the lexicon.

Afferent: Generally, a *connection* or *pathway* to a *node*. 1. The complementary terms *afferent* and *efferent* were first used by Unzer (1771; see English translation, 1851, pp. 69, 254) to indicate toward or away from, respectively, the *central nervous system* (Meckel, 1817) or, conversely, away from or toward the non-neuronal tissues of the *body*; see Sherrington (1900, p. 784), Clarke & O'Malley (1996, p. 342). These neutral terms avoid functional implications that may or may not be valid; for example, *afferent* information from the skin may not be sensory if it does not reach the level of consciousness. 2. A *connection* or *projection* to a *gray matter region*, *neuron type* (Bota & Swanson, 2007), *neuron* (Waldeyer, 1891), or *site*. The preferred synonym is *input*.

Afterbrain (Baer, 1837): Synonym for *medulla* (Winslow, 1733); term introduced for vertebrates by Baer (1837, p. 107, in the original German, *Nachhirn*). Also see His (1895, p. 162).

Amacrine cell: A *neuron* (Waldeyer, 1891) characterized by *amacrine extensions*. They were discovered in the *retina* (Herophilus, 335-263 BC), in the *olfactory bulb* (Weitbrecht, 1744), and in the *peripheral nervous system* (Meckel, 1817) where they are called *interstitial cells*; they were regarded as having no *axon* (Kölliker, 1896), and thus “amacrine” (see Cajal, 1899-1904). Examples of *neurons* with *amacrine extensions* and/or *axon*, and/or *dendrites* (His, 1889) are now known; they are very common in *nerve nets*.

Amacrine connection: A bidirectional *connection* between two *nodes* established by *amacrine extensions* arising in both *nodes* from specific types of *amacrine cells*.

Amacrine extension: A *neuron extension* that in a *chain* normally forms a *reciprocal* (bidirectional) *synapse* (Foster & Sherrington, 1897) with a like extension of another *neuron* (Waldeyer, 1891); that is, an *amacrine extension* may function as an *axon* (Kölliker, 1896) or a *dendrite* (His, 1889) in a *chain*, conducting in either direction depending on functional activity in the *neural network*; see Swanson (2003, pp. 23, 243). An *amacrine extension* may also form unidirectional *synapses*. A synonym is *amacrine process*.

Amacrine process: Synonym for *amacrine extension*; see Swanson (2003, pp. 23, 243).

Anterior (Aristotle): *Rostral* (Schulze, 1893) in relation to the *longitudinal axis* (Barclay, 1803); commonly used in this way for comparative anatomy, as was the case for

Aristotle in *De Partibus Animalium*; see, for example, translation by Ogle (1912, 684b-25). Vicq d'Azyr (1786, pp. 51, 58) first clearly defined the term as in front or toward the face, corresponding in most vertebrates to *rostral*, and in humans to *ventral* (Schulze, 1893) or anterior (Galen, c177). Discarding the ambiguous terms anterior and posterior has been urged since at least 1880 (Spitzka, 1880, p. 75). Formal descriptors of position in anatomy can be traced to this statement by Aristotle in *De Partibus Animalium*, “it is a universal law that, as regards above and below, front and back, right and left, the nobler and more honourable part invariably is placed uppermost, in front, and on the right, rather than in the opposite positions, unless some more important object stands in the way”; see translation by Ogle (1912, 665a; also see 667b, 669b). In *Historia Animalium* he clarified the problems with positional information in comparative anatomy, “In man, above all other animals, the terms ‘upper’ and ‘lower’ are used in harmony with their natural positions; for in him, upper and lower have the same meaning as when they are applied to the universe as a whole. In like manner the terms, ‘in front’, ‘behind’, ‘right’ and ‘left’, are used in accordance with their natural sense. But in regard to other animals, in some cases these distinctions do not exist, and in others they do, but in a vague way. For instance, the head with all animals is up and above in respect to their bodies; but man alone, as has been said, has, in maturity, this part uppermost in respect to the material universe”; see translation by Thompson (1910, 294a-25). Also see Standring (2008, Fig. 1).

Anterior (Galen, c177): *Ventral* (Schulze, 1893) in relation to the *longitudinal axis* (Barclay, 1803); commonly used in this way for human and other primate anatomy, as was the case for Galen; see translation by Singer (1999, p. 129), also see translation by Duckworth (1962, pp. 229, 231). Also see anterior (Aristotle).

Anteroposterior axis: Often used as synonym for *rostrocaudal axis* in most vertebrates and for the *dorsoventral axis* in humans; see Standring (2008, Fig. 1). Application of this old and confusing designation is discouraged; see anterior (Aristotle) and anterior (Galen, c177). Also spelled anterior-posterior axis.

Arachnoid (A; Blasius, 1666): A delicate membrane resembling a spider’s web interposed between *dura* (Galen, c177) and *pia* (Galen, c192), and separated from *pia* by *subarachnoid space* (Magendie, 1827). It is histologically similar to *pia*, and the two are often considered together as *leptomeninges*; see Dorland’s (2003), Standring (2008, p. 389). The *arachnoid* was first illustrated for macrodissected adult humans by Casserio (1627), and described and named by Blasius (1666).

Arachnoidea mater: Synonym for *arachnoid* (Blasius, 1666).

Arborization (Cajal, 1888): Short form of *terminal arborization* (Cajal, 1888).

Architecture: The conceptual structure and overall logical organization of a system—here the *nervous system* (Monro, 1783)—from the point of view of its function or design; see Oxford English Dictionary (1989) and Sherrington (1906, pp. 271, 308).

Autonomic ganglia (GA; Langley, 1900): A *topographic division* of vertebrate *peripheral ganglia* with *gray matter regions* that are distinguished from the *craniospinal ganglia*, and for description are divided into *paravertebral ganglia*, *prevertebral ganglia* (Gaskell, 1886), and *terminal ganglia* (Gaskell, 1886). Galen (c173-c192) described at least three pairs; see translations by Duckworth (1962, pp.

217-218), May (1968, pp. 695-696), Smith (1971, p. 179). The term was introduced by Langley (1900, pp. 677-678).

Autonomic nerves (AUN; Langley, 1898): A *topographic division of nerves* (*Herophilus, c335-280 BC*). An *autonomic nerve* is a vertebrate *nerve* (*Herophilus, c335-280 BC*)—and a communicating or anastomotic network of branches (a *prevertebral plexus* or a *terminal plexus*) sometimes associated with it—that appears macroscopically to arise in the *peripheral nervous system* (*Meckel, 1817*) from an *autonomic ganglion* (*Langley, 1900*) rather than a *craniospinal nerve*. In the second century, Galen—see translations by Singer (1999, p. 142) and Duckworth (1962, p.111)—described at least some of them in animals except humans, and the term was introduced by Langley (1898, p. 241).

Axial plane: Synonym for *transverse plane* (*Henle, 1855*) in human radiology, also referred to as *transaxial* and viewed as if from the feet toward the head; see Standing (2005, p. 3).

Axon (Kölliker, 1896): A *neuron extension* that in a *chain* normally conducts information away from the *dendrites* (*His, 1889*) and/or *cell body* (*Deiters, 1865*) to *axon terminals* (*Barker, 1899*), the *presynaptic compartment* (*De Camilli et al., 2001*) of *synapses* (*Foster & Sherrington, 1897*). Most *neurons* (*Waldeyer, 1891*) have one *axon trunk* with a variable number of *axon collaterals* (*Cajal, 1899*), and the *presynaptic compartment* may be (a) an *axon varicosity* (although not all varicosities form *synapses*) also called a *synapse-of-passage*, (b) a *terminal-of-passage* along the *axon trunk* or *axon collaterals*, or (c) an *axon terminal* (synonym: *terminal bouton*) at the end of an *axon collateral* or the *axon trunk*; see Swanson, 2004, Fig. 5). The *axon* was probably discovered microscopically in unfixed molluscan material by Dutrochet (1824, Pl. 2, fig. 2; see Van der Loos, 1967, pp. 22-23) and for vertebrates by Remak (1837; his primitive band). *Axons* were first distinguished clearly from *dendrites* by Wagner (1846, see Tab. 3, Fig. 43-*a*; see Van der Loos, 1967, p. 37), and named thus by Kölliker (1896, p. 2). It is common in vertebrates for the *axon* to arise from the *cell body* or a *dendrite*, as first demonstrated microscopically in macerated tissue from the *Torpedo* electric organ by Wagner (1846, Tab. 3, Fig. 43-*c*; see Van der Loos, 1967, pp. 38-39).

Axon bifurcation: Y-shaped branching of an *axon trunk*, generating two bifurcation branches (*Cajal, 1899*); discovered in hagfish Golgi material by Nansen (1887, pp. 158, 213, “dichotomous subdivisions of nerve tubes”), named bifurcation by Cajal (1889, Fig. 3 and p. 91).

Axon bifurcation branch: One of the two products of an *axon bifurcation*; discovered in hagfish Golgi material by Nansen (1887, pp. 158, 213), named bifurcation branch by Cajal (1889, pp. 91, 95).

Axon collateral (Cajal, 1899): A branch of an *axon trunk* that is typically thinner than the trunk and arises at a roughly right angle. First pointed out by Deiters (1865, Tab. 1, Fig. 1-*b*; see Van der Loos, 1967, p. 44), Golgi (1873) established their existence with his black reaction and noted their roughly right angle of origin (he called them branches or side fibrils); apparently named by Cajal (1899, p. 329, “collaterals of axons”). A short form is *collateral* (*Waldeyer, 1891*).

Axon connection: A unidirectional *connection* established by an *axon* (*Kölliker, 1896*) or group of *axons* from a *neuron type* (*Bota & Swanson, 2007*) arising in one *node* and

establishing *synapses* (Foster & Sherrington, 1897) in another *node* with another *neuron* or *neuron type* (Bota & Swanson, 2007).

Axon hillock (Schaffer, 1893): The expanded part of an *axon trunk* as it arises from the *cell body* (Deiters, 1865) or *dendrite* (His, 1889) of a *neuron* (Waldeyer, 1891), often distinguished by a relative absence of ribosomes; discovered in macerated microdissected ox spinal cord by Deiters (1865, Tab. 1, fig. 1) and named by Schaffer (1893, p. 850). Also see Peters et al. (1991, pp. 101-108).

Axon terminal (Barker, 1899): A swelling—*terminal* (Cajal, 1899)—at the end of an *axon trunk*, *axon collateral* (Cajal, 1899), or *terminal arborization* (Cajal, 1888) that is *presynaptic* and usually rather simple although more elaborate configurations are found. First illustrated by Deiters (1865, Tab. 1, Fig. 1-*b*; Tab. 2, Fig. 6-*b*; see Van der Loos, 1967, p. 44), first interpreted correctly by Cajal (1888, Tab. I), and named thus by Barker (1899, p. 88, “terminals of one axone”).

Axon trunk: The segment of an *axon* (Kölliker, 1896) that begins at the *distal* (Barclay, 1803) end of the *axon hillock* (Schaffer, 1893) and extends *distally*, typically generating *axon collaterals* (Cajal, 1899) and remaining the thickest part of the overall axonal arborization; it comes to an abrupt end at a bifurcation (Cajal, 1889), when present. Galen in the second century used the term trunk for *nerves* (Herophilus, c335-280 BC) as a whole; see translation by May (1968, pp. 554, 572-573). Remak (1838) discovered that *axons* arise from *neurons* (Waldeyer, 1891).

Axon varicosity: A swelling along an *unmyelinated axon*—or unmyelinated segment of an *axon* (Kölliker, 1896)—that may either form a *bouton-of-passage*, or may not form a *synapse* (Foster & Sherrington, 1897) but simply reflect the presence of one or more mitochondria with a diameter greater than the *axon*. Ehrenberg (1833, p. 453; also see Van der Loos, 1967, Fig. 8) described and named varicose fibers, Cajal (1888, p. 4) described and named varicosities of the neural prolongation [*axon*] in Golgi preparations of avian *cerebellum* (Aristotle).

Axon-of-passage: Segment of an *axon* (Kölliker, 1896) that passes through a *gray matter region* without forming *synapses* (Foster & Sherrington, 1897). Preferable to *fiber-of-passage* (Cajal, 1894a) because more accurate; also see Cowan et al. (1972, p. 38).

Basal ganglia (Ferrier, 1876): In modern terms includes for macrodissected adult monkeys and humans the *cerebral nuclei* (Swanson, 2000) and *interbrain* (Baer, 1837) considered together; pp. 8, 236.

Basal ganglia (Strong & Elwyn, 1943): Synonym for basal ganglia of telencephalon (Ranson, 1920) in macrodissected adult humans, and thus not synonymous with *cerebral nuclei* (Swanson, 2000); p. 319.

Basal ganglia (Warwick & Williams, 1973): Synonym for *cerebral nuclei* (Swanson, 2000); see Warwick & Williams (1973, p. 805; and Williams & Warwick, 1980, p. 864). Its use is discouraged because reference to *ganglia* (Galen, c173) in the *cerebrospinal axis* (Meckel, 1817) is archaic; and because “basal ganglia” today usually refers to a functional system that includes components in the *forebrain* (Goette, 1873) and *midbrain* (Baer, 1837), rather than to a *topographic division* of the *endbrain* (Kuhlenbeck, 1927); see Anthony (1994, pp. 106-109), DeLong & Wichmann (2007), and Federative Committee on Anatomical Terminology (1998, *A14.1.09.501).

- Basal ganglia (Carpenter, 1976): For macrodissected adult humans it includes the caudate and lenticular nuclei and the amygdala, and is thus not synonymous with *cerebral nuclei* (Swanson, 2000); p. 496.
- Basal ganglia of telencephalon (Ranson, 1920): For macrodissected adult humans it includes the caudate and lentiform (putamen and globus pallidus) nuclei, amygdala, and claustrum (p. 252) and is thus not synonymous with *cerebral nuclei* (Swanson, 2000). More recently it was used in Ranson's sense by for example Clark (1951, p. 968).
- Basal nuclei (Clark, 1951): Synonym for basal ganglia (Strong & Elwyn, 1943) in macrodissected adult humans, and thus not synonymous with *cerebral nuclei* (Swanson, 2000); p. 968. Others employing this usage include Warwick & Williams (1973, p. 976; and Williams & Warwick, 1980, p. 1032), International Anatomical Nomenclature Committee (1983, p. A72).
- Basal nuclei (Warwick & Williams, 1973): Synonym for *cerebral nuclei* (Swanson, 2000); see Warwick & Williams (1973, p. 805; and Williams & Warwick, 1980, p. 864) and Swanson (1998, p. 200).
- Basic plan:** A high level model of *nervous system* (Monro, 1783) structure-function organization that only contains minimal, essential, or canonical features; see Jacobson (1991, pp. 6-17), Swanson (2003, 2007). Bauplan (see Kuhlenbeck, 1967, pp. 159-165; Brusca & Brusca, 1990, p. 43) and general plan (see Bullock & Horridge, 1965, p. 11) are synonyms. "General plan of the body" was used as long ago as Aristotle, for example in *De Partium Animalium*; see translation by Ogle (1912, 684b-15).
- Between brain: Synonym for *interbrain* (Baer, 1837). Used by for example Obersteiner & Hill (1900, p. 72), Herrick (1915, p. 121), Williams & Warwick (1980, p. 864), and Nauta & Feirtag (1986, p. 39). 'Tween-brain is also used; see Nauta & Feirtag (1986, p. 38), Nieuwenhuys et al. (2008, p. 9).
- Bifurcation (Cajal, 1889): Short form of *axon bifurcation*; called thus by Cajal (1889, Fig. 3 and p. 91, *bifurcación* in Spanish).
- Bifurcation branch (Cajal, 1889): Short form of *axon bifurcation branch*; called thus by Cajal (1889, pp. 91, 95).
- Bilateral (Aristotle):** On the both sides of the *body* in an animal with *bilateral symmetry*. The term was used thus by Aristotle in *Historia Animalium*; see translation by Thompson (1910, e.g., 493a-15), also see Standring (2008, p. xxii).
- Bilateral symmetry:** Symmetry where only one plane, the *median plane* (Henle, 1855), divides the *body* into roughly mirror image right and left halves, at least when viewed from the exterior. Aristotle in *De Partibus Animalium* laid the foundation for describing animal symmetry and positional information; see translation by Ogle (1912, e.g., 667b), "the body of every sanguineous animal that is capable of locomotion is bilateral; for in such animals there is a distinguishable before and behind, a right and left, an above and below". In *Historia Animalium* he clarified the problems with positional information in comparative anatomy, "In man, above all other animals, the terms 'upper' and 'lower' are used in harmony with their natural positions; for in him, upper and lower have the same meaning as when they are applied to the universe as a whole. In like manner the terms, 'in front', 'behind', 'right' and 'left', are used in accordance with their natural sense. But in regard to

other animals, in some cases these distinctions do not exist, and in others they do, but in a vague way. For instance, the head with all animals is up and above in respect to their bodies; but man alone, as has been said, has, in maturity, this part uppermost in respect to the material universe"; see translation by Thompson (1910, 294a-25). Also see Willmer (1990, p. 15), Brusca & Brusca (1990, p. 46).

Body: The physical or material frame or structure of humans or any other animal; the whole material organism viewed as an organic entity. Aristotle used the term in this sense; see translation by Thompson (1910, Book 1), also see Oxford English Dictionary (1989, definition 1). All *bodies* have an age in the life cycle and a sex (female, male, mixed). In taxonomy, only the physical characteristics common to a taxon (like species) are considered, not the variable physical characteristics of individuals; see Simpson (1961, p. 18).

Body system: A set of interconnected or interdependent parts that forms a complex unity with a specific function; see Dorland's (2003), Oxford English Dictionary (1989). A set of *body systems* together describes completely the structure-function organization of the *body*—a *systems description of body*; see Brash (1951, p. 4), Williams (1995, pp. 2, 15).

Bouton: Short form of *terminal bouton* (Auerbach, 1898).

Bouton-of-passage: A *synapse* (Foster & Sherrington, 1897) formed by an *axon varicosity* (Cajal, 1888); "bouton en passant" in French; see Peters et al. (1991, pp. 150, 187, 358).

Brain (BR; Edwin Smith Surgical Papyrus, c1700 BC): See *invertebrate brain* (>1840) and *vertebrate brain* (Cuvier, 1800). An ancient Egyptian hieroglyph that refers to the human *brain* probably dates back some five thousand years; see Longrigg (1998, p. 84), Nunn (2002, pp. 43, 50-51, 217), and Rocca (2003, p. 21).

Brain (Vesalius, 1543): In modern terms Vesalius's definition of the human brain excluded the *medulla* (Winslow, 1733) and *pons* (Haller, 1747), which he included with the *spinal marrow* (Vesalius, 1543); see translation by Richardson & Carman (2002, pp. 176-177, 205).

Brain (Varolio, 1573): In modern terms Varolio's definition of the human brain (*cerebrum* in Latin) excluded the *cerebellum* (Aristotle), as well as the *midbrain* (Baer, 1837), *pons* (Haller, 1747), and *medulla* (Winslow, 1733), the latter three of which he included in spinal marrow (Varolio, 1573); Fig. 2(1-3) on f. 19r.

Brainstem (Burdach, 1822): Basically a combination of the *brainstem* (Schwalbe, 1881) and the *cerebral nuclei* (Swanson, 2000), or basal ganglia (Warwick & Williams, 1973), as originally defined for macrodissected adult humans; p. 11. It corresponds to the oblong marrow (Willis, 1664), and has been used more recently in Burdach's sense by for example Herrick (1915, p. 114), Ranson & Clarke (1959, Fig. 32).

Brainstem (Schwalbe, 1881): A topographic division of the *vertebrate brain* (Cuvier, 1800) that is a combination of the *medulla* (Winslow, 1733), *pons* (Haller, 1747), *midbrain* (Baer, 1837), and *interbrain* (Baer, 1837), and thus excludes the *endbrain* (Kuhlenbeck, 1927) or *cerebrum* (Obersteiner & Hill, 1900), and the *cerebellum* (Aristotle). Used in this sense by Schwalbe (1881, p. 396), and more recently by for example Mettler, 1948, Fig. 119), Carpenter (1976, pp. 36-37), Nauta & Feirtag (1986, Fig. 69), Brodal (1992, p. 285), Swanson (2003, p. 243).

- Brainstem (Jacobsohn, 1909): A combination of the *medulla* (Winslow, 1733), *pons* (Haller, 1747), and *midbrain* (Baer, 1837) as originally defined for adult humans; p. 1. Used in this sense more recently by for example Olszewski & Baxter (1954, p. 7), Williams (1995, p. 910), Nieuwenhuys et al. (2008, p. 3).
- Bulb: Synonym for *medulla* (Winslow, 1733); introduced for macrodissected adult humans by Chaussier (1807, p. 120).
- Caudal (Cleland, 1879):** Away from the mouth along the *longitudinal axis* (Barclay, 1803) of the *body*; the opposite of *rostral* (Schulze, 1893). Used by Cleland (1879, p. 179) who paired it with cephalic (away from the head or toward the tail). Also see *rostrocaudal axis*.
- Cell (Hooke, 1665):** The fundamental structure-function unit of all plants and animals; see Schwann (1839). Discovered microscopically and named in thin sections of cork by Hooke (1665, p. 112 ff.); see Standring (2008, Ch. 1).
- Cell body (Deiters, 1865):** When referring to *neurons* (Waldeyer, 1891), it is the trophic center exclusive of *neuron extensions*—*axon* (Kölliker, 1896), *dendrites* (His, 1889), and *amacrine extensions*—with a *cell nucleus* (Brown, 1833) and *perikaryon* (Foster & Sherrington, 1897). For neurons the term *cell body* was used by Deiters (1865, *Körper der Zelle* in the original German; see Van der Loos, 1967, p. 42). Also see Standring (2008, p. 41).
- Cell group: Often used as a synonym for *gray matter region*; see Cajal (1909, p. 41), Clark (1938, p. 9), Berman (1968, p. xi), Nauta & Haymaker (1969, pp. 141-142), Swanson (2003, p. 64). Synonyms include cellular aggregate (see Berman, 1968, p. xi), cell collection (see Berman, 1968, p. xi).
- Cell nucleus (Brown, 1833): A rounded organelle in the *cells* (Hooke, 1665) of all organisms except bacteria and similar forms that is enclosed in a double membrane and contains the genetic material of the *cell*; see Oxford English Dictionary (1989). Not to be confused with *gray matter nucleus*. Clearly described and named by Brown (1833, p. 709).
- Center: This term has multiple connotations. It is often used to indicate the *site* of a particular function, or as a rough synonym for *node*. It was used essentially in the latter sense as far back as Manfridi (1490; see Singer 1917, p. 108) and Bartholin (1662, p. 142). Of course *center* can also refer to the middle point of an object.
- Central (Barclay, 1803):** Toward the center of the *body*. Barclay (1803, pp. 120-121, 164) introduced a formal distinction between *central* and *peripheral* (Barclay, 1803), although use of the term as toward the center of the body goes back at least to Aristotle in *De Partibus Animalium*; see translation of Ogle (1912, 672-34).
- Central canal (C; Henle, 1871):** The narrow, sometimes occluded part of the *ventricles* (Hippocrates) that is *caudal* (Cleland, 1879) to the *fourth ventricle* (Galen, c177), in the *caudal* (Cleland, 1879) end of the *medulla* (Winslow, 1733) and in the *spinal cord* (Galen, c162-c166). At least the initial *rostral* (Schulze, 1893) part of the *central canal* of macrodissected adult animals not including humans was observed in the second century by Galen—see translations by De Lacy (1980, pp. 447, 453), May (1968, p. 416), and Duckworth (1962, p. 14)—and was named such by Henle (1871, p. 42), if not earlier.
- Central ganglion (GC):** A *ganglion* (Galen, c173) of an invertebrate *central nerve cord*; see Bullock & Horridge (1965, p. 52).

Central longitudinal communicating branch: The segment of an invertebrate *central nerve cord trunk* between two *central ganglia* associated with the corresponding *central nerve cord* as a whole.

Central nerve cord: For the invertebrate *central nervous system* (Meckel, 1817), a *topographic division* that is a longitudinal *central nerve cord trunk* with a series of more or less regularly spaced *central ganglia* along its course, and a *central nerve cord trunk* segment between two adjacent *central ganglia* called a *central longitudinal communicating branch*. For invertebrates, the *central nervous system* (Meckel, 1817) generally consists of one or more *central nerve cords*, with *central transverse communicating branches*—commonly referred to as commissures—typically interconnecting *central ganglia* between *central nerve cords* (e.g., a right and a left) and forming a ladder-like, or orthogon (see Reisinger, 1925, 1972), arrangement with *rostral* (Schulze, 1893) and *caudal* (Cleland, 1879) ends. The most *rostral* of the *central ganglia* is commonly called the *invertebrate brain* or cerebral ganglion. In annelids and arthropods the most *rostral* of the *central ganglia* generally lies *dorsal* (Barclay, 1806) to the *digestive system* and is called the *supraesophageal ganglion*, whereas the rest of the *central nerve cord* lies *ventral* (Schulze, 1893) to the *digestive system*. See Bullock & Horridge (1965).

Central nerve cord trunk: The equivalent of a *white matter tract* for an invertebrate *central nerve cord*, with *central ganglia* distributed along its length.

Central nervous system (CNS; Meckel, 1817): In animals with *bilateral symmetry*, a *topographic division* that is an obvious condensation of the *nervous system* (Monro, 1783) in the *longitudinal plane* (Henle, 1855), lying on or near the *median plane* (Henle, 1855). For invertebrates this longitudinal division consists of one or more *nerve cords*, whereas for vertebrates it consists of a single, hollow, and *dorsal* (Barckay, 1803) *cerebrospinal axis* (Meckel, 1817). In adult Echinoderms, which are radially symmetrical, a presumptive CNS is formed by a *circular cord* with associated *radial cords*, but there is no dominant *ganglion* (Galen, c173) that could be considered an *invertebrate brain*; see Bullock & Horridge (1965, pp. 9-14), Heinzeller & Welsch (2001, p. 41). When a CNS is present, its obligate companion *topographic division* is a *peripheral nervous system* (Meckel, 1817). While a continuous *brain* (Edwin Smith Surgical Papyrus, c1700 BC) and *spinal cord* (Galen, c162-c166) were known to Hippocrates in *On the Sacred Disease* and *Fleshes* (see translations by Adams, 1972, p. 351; and Potter, 1995, p. 139, respectively), the term *central nervous system* as currently understood for vertebrates was first used by Meckel (1817; see English translation, 1832, vol. 1, p. 152).

Central transverse communicating branch: The equivalent for invertebrates of a *white matter tract* interconnecting two *central ganglia* on different *central nerve cords*, like the rungs of a ladder.

Cerebellum (CB; Aristotle): The *dorsal* (Barclay, 1803) *topographic division* of the *hindbrain* (Baer, 1837), connected to the *ventral* (Schulze, 1893) division—the *pons* (Haller, 1747)—by a *white matter tract*, the *middle cerebellar peduncle*. The *cerebellum* was discovered and named by Aristotle (in *De Partibus Animalium*) based on macrodissection of a variety of animals not including humans; see translation by Thompson (1910, 494b 30). Older synonyms include *parencephalon* (Aristotle), *hindbrain* (Galen, c192).

Cerebral aqueduct (AQ; His 1895): The part of the *ventricles* (*Hippocrates*) in the *median plane* (*Henle, 1855*) of the *midbrain* (*Baer, 1837*), continuous *rostrally* (*Schulze, 1893*) with the *third ventricle* (*Galen, c173*) and *caudally* (*Cleland, 1879*) with the *fourth ventricle* (*Galen, c177*). Vesalius (1543; see translation by Singer, 1952, p. 36; also see May, 1968, pp. 420-423) first clearly described it in macrodissected adult humans, Aranzi (1587, p. 549) first called it an aqueduct, and His (1895, p. 83) called it the *cerebral aqueduct* for macrodissected adult humans.

Cerebral cortex (CTX; Bauhin, 1605): The *dorsal* (*Barclay, 1803*) *topographic division* of the *endbrain* (*Kuhlenbeck, 1927*), with a basically radial, laminated architecture; the *ventral* (*Schulze, 1893*) *topographic division* is the *cerebral nuclei* (*Swanson, 2000*). The *cerebral cortex* was described and illustrated for macrodissected adult humans by Vesalius (1543), see Singer translation (1952, p. 100 and Fig. 7), and the term itself was introduced for macrodissected adult humans by Bauhin (1605, p. 580), see Meyer (1971, p. 121). Common synonym is *pallium* (*Burdach, 1822*).

Cerebral ganglia (*Reil, 1809*): Basically synonymous with macrodissected adult human *cerebral nuclei* (*Swanson, 2000*); see Mayo translation (1823, p. 52).

Cerebral ganglion: Synonym for *invertebrate brain*; see Bullock & Horridge (1965, p. 1609).

Cerebral hemispheres (*Tiedemann, 1816*): Synonym for *endbrain* (*Kuhlenbeck, 1927*). It was used in this way by Tiedemann (see 1826 translation, p. 15), and more recently by for example Strong & Elwyn (1943, pp. 13-16), Carpenter (1976, p. 21), Williams & Warwick (1980, p. 864), and Nauta & Feirtag (1986, p. 43), but has also been defined in many other ways.

Cerebral nuclei (CNU; Swanson, 2000): The *ventral* (*Schulze, 1893*) *topographic division* of the *endbrain* (*Kuhlenbeck, 1927*), with a basically nonlaminated architecture; the *dorsal* (*Barclay, 1803*) division is the *cerebral cortex* (*Bauhin, 1605*). The general outlines of the *cerebral nuclei* were described for macrodissected adult humans by Bartholin (1651; see English translation 1662, p. 141), and a basic distinction during embryogenesis between *cerebral cortex* and *cerebral nuclei* was stressed by Baer (1837) and Reichert (1859-1861). The most common synonym today for *cerebral nuclei*, which was clearly defined by Swanson (2000, p. 117; 2004, pp. 166-170), is *basal ganglia* (*Warwick & Williams, 1973*); also see *ganglion* (*Galen, c173*). Other synonyms include *corpus striatum* (*Willis, 1664*), *cerebral ganglia* (*Reil, 1809*), and *basal nuclei* (*Warwick & Williams, 1973*). *Cerebral nuclei* (*Swanson, 2000*) is preferred to the synonym *basal nuclei* (*Warwick & Williams, 1973*) because it pairs naturally with *cerebral cortex* (*Bauhin, 1605*).

Cerebral peduncle (cpd; Tarin, 1753): The large compact *white matter tract* of macrodissected adult mammals descending *laterally* (*Barclay, 1803*) and *ventrally* (*Schulze, 1893*) in the *interbrain* (*Baer, 1837*) and *tegmentum* (*Swanson, 2000*) of the *midbrain* (*Baer, 1837*), as a continuation of the *internal capsule* (*Burdach, 1822*). It was clearly illustrated for macrodissected adult humans by Casserio (1609, pp. 123-124, Tab. VII, Fig. 2-C) and Tarin (1753, p. 25) gave its current name, which was followed by Burdach (1822, p. 99; in Latin, *crus cerebri*).

Cerebral peduncle (*Vicq d'Azyr, 1784*): Synonym for macrodissected adult human *tegmentum* (*Swanson, 2000*); pp. 555-556. Later used thus by for example His

(1893b, p. 178), Herrick (1915, p. 160), Strong & Elwyn (1943, p. 17), Carpenter (1976, p. 367), Williams & Warwick (1980, p. 935).

Cerebral ventricles: Synonym for *ventricles* (*Hippocrates*).

Cerebrospinal axis (CSA; Meckel, 1817): In popular usage it is a *topographic division* that corresponds to the vertebrate *central nervous system* (*Meckel, 1817*), although in fact it applies more generally to the chordate *central nervous system* (*Meckel, 1817*), a hollow tubular division of the *nervous system* (*Monro, 1783*) that lies in the *median plane* (*Henle, 1855*), *dorsal* (*Barclay, 1803*) to a notochord and flanked by a *bilateral* (*Aristotle*) series of segmental muscles (*Nieuwenhuys, 2002*). Since Classical Antiquity at least six fundamentally different ways to divide the *cerebrospinal axis* have been used, although today there is rather broad consensus about a set of major *topographic divisions of cerebrospinal axis*. The set of divisions is arranged in a hierarchical parceling scheme that is based primarily on structural differentiation of the *neural tube* (*Baer, 1837*) and its end product is adult macrostructure or gross anatomy (*Swanson, 2000*). The term *cerebrospinal axis* was introduced by Meckel (1817; see English translation, 1832, vol. 2, p. 410) for macrodissected adult humans although the feature itself was known to Herophilus (335-280 BC; see von Staden, 1989, p. 159).

Cerebrum (*Vesalius, 1543*): Synonymous with *forebrain* (*Goette, 1873*) together with *midbrain* (*Baer, 1837*); see Singer translation (1952, pp. 36, 46-47). Also see His (1895, p. 162).

Cerebrum (*Varolio, 1573*): Synonymous with *forebrain* (*Goette, 1873*); see Clarke & O'Malley (1996, pp. 635, 881-882).

Cerebrum (*Obersteiner & Hill, 1900*): Synonym for *endbrain* (*Kuhlenbeck, 1927*). It was used in this way by for example *Obersteiner & Hill* (1900, pp. xv, 47), *Crosby et al.* (1962, p. 356), *Williams & Warwick* (1980, p. 864), *Nauta & Feirtag* (1986, p. 43), and *Nieuwenhuys et al.* 2008, p. 5, Fig. 1.2), but has also been defined in many other ways. Curiously, in English, the Greek (encephalon) and Latin (cerebrum) forms of “brain” are not synonymous (see *Oxford English Dictionary, 1989*). This goes back to *Aristotle*, who distinguished a large brain (cerebrum) and small brain (cerebellum, the diminutive of cerebrum); see *Swanson* (2000) and *His* (1895, p. 162).

Chain: The sequence or series of *connections* between an arbitrary set of *nodes*. There are *open chains* and *closed chains*; synonyms for the latter are circuit, loop, and cycle. *Chain* is a traditional term to describe *neural network* organization and has been widely used in this sense at least since *Foster & Sherrington* (1897, p. 979), *Barker* (1899, pp. 313-320), *Schäfer* (1900, vol. 2, p. 608).

Chemical synapse: A *synapse* (*Foster & Sherrington, 1897*) using only neurotransmitters for communicating between the *presynaptic compartment* (*De Camilli et al., 2001*) and *postsynaptic compartment* (*De Camilli et al., 2001*); see *Cowan et al.* (2001).

Circuit: Synonym for *closed chain*. Generally, a circuit is a closed path that begins and ends in the same place (*Oxford English Dictionary, 1989*). In graph theory it is also called a cycle.

Circuitry: A vague term referring to all or part of the *connectome* or complete *wiring diagram*; it should be avoided, see circuit.

Circular cord: Synonym for *circumoral nerve ring*; see *Bullock & Horridge* (1965, p. 12).

- Circumenteric nerve ring:** Regarded as the *central nervous system* (Meckel, 1817) of Nematodes and Priapulids; see Bullock & Horridge (1965, pp. 605, 658).
- Circumoral nerve ring:** The *nerve ring* in adult Echinoderms, where there is no convincing evidence that the *nervous system* (Monro, 1783), which is a *nerve net*, is divided into *central nervous system* (Meckel, 1817) and *peripheral nervous system* (Meckel, 1817); see Bullock & Horridge (1965, p. 1525), Cobb (1995, p. 411). There is also a *circumoral nerve ring* with a *ganglion* (Galen, c173) in Phoronida; see Bullock & Horridge (1965, p. 641).
- Closed chain:** A series of *connections* in a topological circle; that is, one can start at any *node* and follow *connections* back to the same *node*; synonyms include circuit, loop, and cycle.
- Collateral (Waldeyer, 1891): Short form of *axon collateral* (Cajal, 1899); name provided by Waldeyer (1891; see Shepherd, 1991, p. 36).
- Commissure:** When a *white matter tract* crosses the *median plane* (Henle, 1855) in animals with *bilateral symmetry* and then assumes a transverse course, the crossing segment is called a *commissure*. Generally, a *commissure* forms *connections* between the same or nearby *gray matter regions* on the right and left sides. The term was used in this sense as long ago as Willis (1664, see translation by Pordage, 1681, p. 159). Also see Nauta & Feirtag (1986, p. 82, note).
- Communicating branch (cbr; Winslow, 1733):** A general term for a short *white matter tract* between two *nerve cords*, two *nerves* (Herophilus, c335-280 BC), two *ganglia* (Galen, c173), or a *ganglion* and a *nerve*. Galen (c180; see translation by Goss, 1966, p. 330) referred to communications between *nerves* and Winslow (1733, Sect. VI) frequently used the term *communicating branch* in describing macrodissected adult human *nerves*.
- Connection:** The overall structural link between two *nodes* in the *wiring diagram* of the *nervous system* (Monro, 1783); synonyms include structural connection and projection. The *nodes* may be described at three successively greater levels of resolution and accuracy. For a *macroconnection* (Thompson & Swanson, 2010) the two *nodes* are *gray matter regions*, for a *mesoconnection* (Thompson & Swanson, 2010) the *nodes* are *neuron types* (Bota & Swanson, 2007), and for a *microconnection* (Thompson & Swanson, 2010) the *nodes* are individual *neurons* (Waldeyer, 1891). A *node* can establish one or more *connections* that are either an *intranodal connection(s)* or an *internodal connection(s)*. An *axon connection* is unidirectional, whereas an *amacrine connection* (amacrine extension connection) is bidirectional. The physical course taken by a connection through *gray matter regions* and *white matter tracts* is called its *route*, and route information is part of the description of a *connection*. Information about a set of *connections* can be arranged in a number of different ways like a *wiring diagram*, *connectome*, or *basic plan*. A closely related concept is *pathway*—the part of a *connection* demonstrated in a particular experimental analysis; another related term is functional connection. “Connections” between parts of the *vertebrate brain* (Cuvier, 1800) were described at least as early as Gordon (1817, p. 134); for its use as defined here see Bota et al. (2003, p. 795). Also see *connections*.
- Connections:** The total *input-output* relationships of a *node* or set of *nodes*, in contrast to an individual *connection*.

- Connectome (here):** For the *Foundational Model of Connectivity*, the complete structural *connection* matrix of *nodes* forming the *nervous system* (Monro, 1783) of a particular animal species, or in a more limited sense the complete input/output *connection* matrix of a particular *node*; also see connectome (Sporns et al., 2005).
- Connectome (Sporns et al., 2005): A “connection matrix of the human brain ... a comprehensive structural description of the network of elements and connections forming the human brain”; p. 245.
- Contralateral:** On the opposite side of the *body* in an animal with *bilateral symmetry*; see Standring (2008, p. xxii).
- Coronal plane (Barclay, 1803): Synonym for *frontal plane* (Henle, 1855), named for the human coronal suture, named in turn for the crown of the human head; p. 145. It is commonly used thus in human and other primate anatomy; see Standring (2008, Fig. 1). It is often confusingly used in quadrupeds for *transverse plane* (Henle, 1855); see coronal plane (Paxinos & Watson, 1982).
- Coronal plane (Paxinos & Watson, 1982): Synonym for *transverse plane* (Henle, 1855); p. 2. Used occasionally in comparative anatomy, probably before Paxinos & Watson (1982). Also see coronal plane (Barclay, 1803).
- Corpora quadrigemina (Winslow, 1733): Synonym for macrodissected adult human *tectum* (Schwalbe, 1881); Sect. X, p. 37. Quadrigeminal body in English.
- Corpus striatum (Willis, 1664): Basically synonymous with *cerebral nuclei* (Swanson, 2003) as Willis defined the term for macrodissected large mammals including humans; pp. 62-63, 101-102, Tab. VIII-A. Striate body in English.
- Cranial nerve ganglia (GCR):** The *topographic division* consisting of sensory *ganglia* (Galen, c173) associated with the *cranial nerves* (Longet, 1842), in contrast to the *autonomic ganglia* (Langley, 1900) associated with the *cranial nerves* (Longet, 1842); see International Anatomical Nomenclature Committee (1983; p. A73), Federative Committee on Anatomical Terminology (1998, p. 132).
- Cranial nerves (cran; Longet, 1842):** The *topographic division* of vertebrate *craniospinal nerves* (Herrick, 1915) that exit the cranium despite their origin; for example the *spinal root of accessory nerve*, which is motor in function, arises from the ventral horn of the *spinal cord* (Galen, c162-c166) but exits the cranium with the *vagus nerve* (Galen, c192 AD), another *cranial nerve*. Most of them were known to Herophilus (335-280 BC), the founder of human anatomy (see Solmsen, 1961; von Staden, 1989), and the term itself was first used for macrodissected animals except humans by Galen in the second century, although not in the currently accepted sense; see translations by Duckworth (1962, pp. 181-222) and May (1968, pp. 31-32, 438-454). The traditional division into 12 *cranial nerves* is based on the work of Soemmerring (1778, pp. 173-180), who later called them cerebral nerves (Soemmerring, 1791, sections 128, 203-272); they were finally called the 12 *cranial nerves* by Longet (1842, vol. 2, p. 1).
- Craniospinal ganglia (GCS):** A *topographic division* of vertebrate *peripheral ganglia* that includes *cranial nerve ganglia* and *spinal nerve ganglia* (Burdach, 1819) considered together, all of which are sensory in function and contrasted with the *autonomic ganglia* (Langley, 1900). The history of their discovery is complex, beginning with the discovery of *spinal nerve ganglia* by Coiter (1572, see 1995

translation p. 115). Also see International Anatomical Nomenclature Committee (1983; p. A73), Federative Committee on Anatomical Terminology (1998, p. 132).

Craniospinal nerves (CSN; Herrick, 1915): A *topographic division* of vertebrate nerves (Herophilus, c335-280 BC) consisting of the 12 traditional pairs of *cranial nerves* (Longet, 1842) and the variable number in different species of pairs of *spinal nerves* (Camper, 1760) considered together, and distinguished from the *autonomic nerves* (Langley, 1898). Most *craniospinal nerves* were known to Herophilus (335-280 BC), the founder of human anatomy (see Solmsen, 1961; von Staden, 1989), and the term itself was used by Herrick (1915, p. 223), and later by others including Williams & Warwick (1980, p. 1052).

Cycle: In graph theory a synonym for *closed chain* or circuit.

Decussation: When a *white matter tract* crosses the *median plane* (Henle, 1855) in animals with *bilateral symmetry* and then assumes a longitudinal course, the crossing segment is called a *decussation*. The term was used in this sense at least as long ago as Collins (1685, p. 1045). Also see Nauta & Feirtag (1986, p. 82, note).

Deep (Galen, c173): A relationship between adjacent objects in the *body*; an object is deep to another when it is closer to the center; the opposite of *superficial*. The dichotomy has been used at least since the second century by Galen; see translation by May (1968, pp. 701, 715), also see Standring (2008, p. xxii).

Dendrite (His, 1889): A *neuron extension* that in a *chain* normally conducts information toward the *cell body* (Deiters, 1865) and/or *axon* (Kölliker, 1896). Most vertebrate *neurons* (Waldeyer, 1891) have multiple *dendrites* extending from the *cell body* whereas most invertebrate *neurons* have multiple *dendrites* extending from the *axon*. *Dendrites* were first detected by Valentin (1836; see Van der Loos, 1967, p. 26), the *axon* was first distinguished clearly from *dendrites* by Wagner (1846, see Tab. 3, Fig. 43-a; see Van der Loos, 1967, p. 37), and the *dendrite* was named thus by His (1889, p. 363). For vertebrates they typically branch at acute angles whereas axons branch at approximately right angles (Golgi, 1873).

Dendritic spine (Cajal, 1899): A short thin extension from a *dendrite* (His, 1889) that typically comes off at roughly a right angle. The extension may or may not have a swelling on the end; when it does, the swelling (spine head) is typically *postsynaptic*. They were discovered and named spines by Cajal (1888, p. 4, *espinas* in Spanish) and named *dendritic spines* by Cajal (1899-1904, vol. 1, Fig 14); also see Peters et al. (1991, p. 92), Alvarez & Sabatini (2007).

Distal (Barclay, 1803): Toward the end of an object like a tentacle, limb, or nerve; opposite of *proximal* (Barclay, 1803). Introduced by Barclay (1803, pp. 124-125, 164), also see Standring (2008, p. xxii).

Diencephalon (Sharpey et al., 1867): Original Latin form of *interbrain* (Baer, 1837); p. 577.

Diffuse nerve net: Synonym for *nerve net*, though it usually implies a relative lack of *marginal ganglia* and *nerve rings*; see Bullock & Horridge (1965, p. 463).

Division: Shortened form of *topographic division*.

Dorsal (Barclay, 1803): Toward the back of the *body*, or away from the belly, in the *transverse plane* (Henle, 1855); the opposite of *ventral* (Schulze, 1893); introduced formally by Barclay (1803, pp. 120, 162), who paired it with sternal. At least by the second century Galen had indicated its use, for example, in describing a direction

“back toward the *dorsum*”; see translation by May (1968, p. 701). In Aristotle’s *De Partibus Animalium*, there is reference to “on their [univalves] dorsal surface they have a shell”; see translation by Ogle (1912; 679b, 23-24). Also see Brusca & Brusca (1990, p. 46).

Dorsoventral axis: In animals with *bilateral symmetry* an axis orthogonal to the *rostrocaudal axis* that lies in the *median plane* (Henle, 1855); see Kuhlenbeck (1973, p. 112 and Fig. 34C-ZZ).

Dura (D; Galen, c177): The outermost, toughest, and most fibrous of the three *meninges* (Edwin Smith Surgical Papyrus, c1700 BC); see Dorland’s (2003). It was known to Hippocrates in *Places in Man* and *Fleshes* (see translation by Potter, 1995, pp. 23, 155, respectively) and named such by Galen (c177; see translation by Wiberg, 1914, p. 21).

Dura mater (Ali ibn’ ul-Abbas, d994): Synonym for *dura* (Galen, c177); for naming see translation by Wiberg (1914, p. 86).

Effector (Sherrington, 1906): A non-neuronal *cell* (Hooke, 1665) receiving *input* from a *neuron* (Waldeyer, 1891) and producing a response like contraction or secretion; pp. 6-7, 309.

Efferent: Generally, a *connection* or *pathway* from a *node*. 1. The terms *afferent* and *efferent* were first used by Unzer (1771; see English translation, 1851, pp. 69, 254) to indicate toward or away from, respectively, the *central nervous system* (Meckel, 1817) or, conversely, away from or toward the non-neuronal tissues of the body; see Sherrington (1900, p. 784), Clarke & O’Malley (1996, p. 342). These neutral terms avoid functional implications that may or may not be valid; for example, *afferent* information may not be sensory if it does not reach the level of consciousness. 2. A *connection* or *projection* from a *gray matter region*, *neuron type* (Bota & Swanson, 2007), *neuron* (Waldeyer, 1891), or *site*. The preferred synonym is *output*.

Electrical synapse: A *synapse* (Foster & Sherrington, 1897) based strictly on the flow of ions, rather than neurotransmitters; see Peters et al. (1991, pp. 203-207), Bennett (2000).

Electrotonic synapse: Synonym for *electrical synapse*; see Peters et al. (1991, pp. 203-210).

Encephalon (Homer, c9th century BC): Synonym for *vertebrate brain* (Cuvier, 1800).

Homer (c9th century BC) used this Greek term in referring to the marrow within the skull or head; see Longrigg (1998, p. 168) and Rocca (2003, pp. xvii, 21).

Endbrain (EB; Kuhlenbeck, 1927): The *rostral* (Schulze, 1893) and *dorsal* (Barclay, 1803) *topographic division* of the *forebrain* (Goette, 1873); the *caudal* (Cleland, 1879) and *ventral* (Schulze, 1893) division is the *interbrain* (Baer, 1837). This basic division of the macrodissected adult human *brain* (Edwin Smith Surgical Papyrus, c1700 BC) has been recognized at least since Mondino (1316), see translation by Singer (1925, vol. 1, p. 92), and was named thus by Kuhlenbeck (1927, chs. 3, 10). This English form of *telencephalon* (Kuhlenbeck, 1927) has been used routinely, for example by Herrick (1915, p. 121), Clark (1951, p. 854), Williams & Warwick (1980, p. 982), and Nauta & Fiertag (1986, p. 39). Synonyms include secondary forebrain (Sharpey et al., 1867), telencephalon (Kuhlenbeck, 1927), cerebrum (Obersteiner & Hill, 1900), cerebral hemispheres (Tiedemann, 1826).

End bulb (Held, 1897): Synonym for *axon terminal* (Barker, 1899); named by Held (1897).

Epecephalon (Sharpey et al., 1867): Original Latin form of *hindbrain* (Baer, 1837); p. 577.

Epecephalon (Owen, 1868): Synonym for macrodissected adult vertebrate *rhombicbrain* (His, 1893b); p. 79.

Epecephalon (Mihalkovics, 1877): Synonym for afterbrain (Baer, 1837), that is, the *medulla* (Winslow, 1833); p. 25.

Ephapse: Although sometimes used to mean *electrical synapse*, it has many connotations and should be avoided without careful definition; see Bennett (2000, p. 17).

External: Synonym for *outer* (Galen, c173). The term was used by Aristotle in *De Partibus Animalium*; see translation by Ogle (1912, e.g., 685b-25), also see Barclay (1803, p. 116), Standring (2008, p. xxii).

Extrinsic connection: Often a synonym for *interregional connection*, though its meaning can be vague and its use is thus discouraged.

Extrinsic pathway: Often a synonym for *interregional pathway*, though its meaning can be vague and its use is thus discouraged.

Fiber-of-passage (Cajal, 1894a): Segment of a *nerve fiber* (Ehrenberg, 1833) that passes through a *gray matter region* or a *white matter tract* without forming *synapses* (Foster & Sherrington, 1897); used by Cajal at least as early as 1894 (1894a, p. 173). Also see axon-of-passage and Cowan et al. (1972, p. 38).

Forebrain (Baer, 1837): Synonym for adult vertebrate *endbrain* (Kuhlenbeck, 1927); in the original German, *Vorderhirn*; p. 107. For later use see Ariëns Kappers (1929, Figs. 44, 45), Papez (1929, Ch. 40).

Forebrain (FB; Goette, 1873): The most *rostral* (Schulze, 1893) of the three primary brain vesicles of the vertebrate *neural tube* (Baer, 1837) that divides and develops into the adult *endbrain* (Kuhlenbeck, 1927) and *interbrain* (Baer, 1837). The adult *forebrain* is a *topographic division* lying *rostral* to the *midbrain* (Baer, 1837) that was identified by Varolio (1573), who called it the cerebrum in macrodissected humans, see Clarke & O'Malley (1996, pp. 635, 881-882). The primary forebrain vesicle was identified and named such for the embryonic vertebrate *neural tube* by Baer (1837, p. 106; *vordere Hirnbläschen* in German), and the corresponding part in adults was named by Goette in toads (1873, p. 400). A current synonym is the Latin prosencephalon (Mihalkovics, 1877).

Foundational Model of Connectivity (FMC; here): Abbreviated form of “Foundational Model of Structural Connectivity in the Nervous System”. The term is derived from Foundational Model of Anatomy (FMA); see Brinkley (1991).

Fourth ventricle (V4; Galen, c177): The rhombic-shaped part of the *ventricles* (Hippocrates) in the *rhombicbrain* (His, 1893b), continuous *rostrally* (Schulze, 1893) with the *cerebral aqueduct* (His, 1895) and *caudally* (Cleland, 1879) with the *central canal* (Henle, 1871). The cerebrospinal fluid in the *fourth ventricle* communicates with cerebrospinal fluid in the *subarachnoid space* (Magendie, 1827) through one or more holes in the roof of the *fourth ventricle*. The *fourth ventricle* was known from macrodissected adult humans to Herophilus (335-280 BC; see von Staden, 1989, pp. 247-248), and named such by Galen (c177, c192; see translations by Duckworth, 1962, p. 19 and Singer, 1999, p. 235, respectively).

Frontal plane (Henle, 1855): In animals with *bilateral symmetry*, the plane of section that is parallel to the *longitudinal axis* (Barclay, 1803) and passes *medial* (Schulze, 1893)-*lateral* (Barclay, 1803), orthogonal to the other longitudinal plane, the *sagittal plane* (Henle, 1855); divides the *body* into *dorsal* (Barclay, 1803) and *ventral* (Schulze, 1893) parts. The term was introduced by Henle (1855, p. 1); also see Kuhlenbeck (1973, p. 114), Brusca & Brusca (1990, Fig. 4-A), Romer (1962, p. 7), Sandring (2008, p. xxii). In quadrupeds it is often confusingly synonymous with *transverse plane* (Henle, 1855)—see frontal plane (Horsley & Clarke, 1908)—but it has long been argued that positional terms referring to the horizon or other external landmarks, rather than to internal landmarks, be avoided, especially in comparative anatomy; see Wilder & Gage (1882, pp. 21-23).

Frontal plane (Horsley & Clarke, 1908): A synonym for *transverse plane* (Henle, 1855), commonly used in comparative anatomy. Horsley & Clarke (1908, p. 52) adopted this terminology for use in a stereotaxic instrument and it was adopted for mammals in general, especially in atlases. Also see *frontal plane* (Henle, 1855).

Functional connection: This term has multiple meanings; originally it referred to the physiology of a *connection* (structural connection), or the observation that a *connection* actually works. More recently it is used in functional imaging research to indicate that changes in *nervous system* (Monro, 1783) activity patterns are correlated in time, without direct evidence for structural connections; see Horwitz (2003).

Ganglia (G; Galen, c173): A *ganglion* is a recognizable aggregation of *neurons* (Waldeyer, 1891). There are *marginal ganglia* associated with invertebrate *nerve nets*, *central ganglia* associated with invertebrate *central nerve cords*, and *peripheral ganglia* in the invertebrate and vertebrate *peripheral nervous system* (Meckel, 1817). For vertebrates it has long been best practice to restrict the term *ganglion* (and terms derived from *ganglion*) to structures of the *peripheral nervous system* (Meckel, 1817). As Herrick wrote, “The term ‘ganglion’ is also sometimes used for nuclei or centers within the brain...but this usage is objectionable, for the use of the word *ganglion* in vertebrate neurology should be restricted to collections of neurons outside the central nervous system, such as the ganglia of the cranial and spinal nerves and the sympathetic [autonomic] ganglia.” (1915, p. 108). A prime example is the use of “basal ganglia” for *cerebral nuclei* (Swanson, 2000). Discovered and named in macrodissected adult mammals by Galen (c173; see translation by May, 1968, pp. 695-696).

Ganglionic ring: Synonym for *nerve ring*; see Bullock & Horridge (1965, p. 13).

Glia (Virchow, 1846): The so-called supporting *cells* (Hooke, 1665) of the *nervous system* (Monro, 1783) that are divided into four major embryonic lineages: astrocytes (including ependymal cells), oligodendrocytes, Schwann cells, and microglia. Virchow is usually given credit for discovering and naming *glia* (1846, pp. 247-248; also see Virchow, 1856).

Glial cells: Synonym for *glia* (Virchow, 1846).

Gray matter (GM; Meckel, 1817): Since the 16th century the *nervous system* (Monro, 1783) has been divided more and more precisely into *gray matter* and *white matter* (Meckel, 1817) based on their appearance in freshly dissected material observed with the naked eye—*topographic macroarchitecture of nervous system*; since the 19th

century this differentiation has been made at the histological (*subsystems microarchitecture of nervous system*) level. *Gray matter* is the *nervous system* compartment that consists of the *cell bodies* (Deiters, 1865) of *neurons* (Waldeyer, 1891); the cytoplasmic *neuron extensions*: *axons* (Kölliker, 1896), *dendrites* (His, 1889), and *amacrine extensions*; and *synapses* (Foster & Sherrington, 1897) between the *neuron extensions*—as well as *glia* (Virchow, 1846) and parts of the *circulatory system*: *vascular cells*. *Neuropil* (Waldeyer, 1891) refers to the *gray matter* compartment exclusive of *cell bodies* and *vascular cells* (blood vessels) and thus consists of the cytoplasmic extensions of *neurons* and *glia*, including *synapses*. There is often a fuzzy border of variable and difficult to measure width between *white matter* and *gray matter*. For early history see Clarke & O'Malley (1996, Ch. 10); for modern histological interpretation see Peters et al. (1991), Swanson (2003, pp. 60-66). The general term *nervous system gray matter* as defined here was probably first used by Meckel for macrodissected adult humans (1817, see English translation, 1832 vol. 2, pp. 152-154, 166-167); also see Herrick (1915, p. 108).

Gray matter nucleus: A term applied to many *gray matter regions* in the *cerebrospinal axis* (Meckel, 1817), usually though not always (e.g., the human dorsal lateral geniculate nucleus) when they have relatively clear borders and are nonlaminated. The first use of the term in this way was by Ludwig (1779, Fig. 2b, p. 36); the *cell nucleus*, a cytological feature, was named by Brown (1833, p. 710).

Gray matter region: A recognizable volume of *gray matter* (Meckel, 1817) in the *nervous system* (Monro, 1783) that is distinguished by a unique set of *neuron types* (Bota & Swanson, 2007) with a unique spatial distribution. The entire *gray matter* is regionalized and individual regions may contain *white matter* (Meckel, 1817), including *axons-of-passage*, which are *axons* (Kölliker, 1896) passing through without forming *synapses* (Foster & Sherrington, 1897). The traditional way to view regionalization is with a Nissl stain, whose interpretation is based on methods that identify *neuron types* (Bota & Swanson, 2007) and their spatial distribution; see Brodal (1981, p. 4), Swanson (2004, p. 8). Examples of *gray matter regions* include cerebral cortical areas, thalamic nuclei, and peripheral nervous system ganglia. As a complete set, *gray matter regions* can be arranged in various different ways, for example, *topographic arrangement of gray matter regions* and *subsystems arrangement of gray matter regions*. Older synonyms include gray mass (Meynert 1872, p. 651), gray matter mass (Meynert, 1872, p. 654).

Heterogeneous tract: A *white matter tract* with two or more *mesoconnections* (Thompson & Swanson, 2010) within it.

Hindbrain (Galen, c192): Synonym for *cerebellum* (Aristotle); see translation by Duckworth (1962, p. 18).

Hindbrain (HB; Baer, 1837): *Rostral* (Schulze, 1893) half of the primary hindbrain vesicle (Baer, 1837) of the vertebrate *neural tube* (Baer, 1837) as it develops into the adult *cerebellum* (Aristotle), which lies *dorsally* (Barclay, 1803), combined with the *pons* (Haller, 1747), which lies *ventrally* (Schulze, 1893); p. 107, in the original German, *hinterhirn*. The term for this *topographic division* has been used in this sense more recently, for example by His (1895, p. 162), Obersteiner & Hill (1900, p. 46). The term is derived from the fact that since the time of Aristotle and Galen the *cerebellum*, often combined with the *pons*, was routinely considered the posterior

brain, hindbrain, or small brain, whereas in contrast the cerebrum was often considered the anterior brain, forebrain, or large brain; see Swanson (2000). Synonyms include epencephalon (Sharpey et al., 1867), secondary hindbrain (Sharpey et al., 1867), metencephalon (Huxley, 1871).

Hindbrain (Huxley, 1871): Synonym for macrodissected adult human *rhombicbrain* (His, 1893b); p. 58. Used thus recently by for example Carpenter (1976, p. 58), Nauta & Feirtag (1986, p. 38), Williams et al. (1989, p. 949), Nieuwenhuys et al. (2008, p. 1).

Homogeneous tract: A *white matter tract* with a single *mesoconnection* (Thompson & Swanson, 2010) within it.

Horizontal plane (Henle, 1855): Synonym for *transverse plane* (Henle, 1855); introduced by Henle (1855, p. 1), see Standring (2008, Fig. 1). It is often confusingly used in quadrupeds for *frontal plane* (Henle, 1855); see horizontal plane (Horsley & Clarke, 1908).

Horizontal plane (Horsley & Clarke, 1908): A synonym for *frontal plane* (Henle, 1855), commonly used in comparative anatomy. Horsley & Clarke (1908, p. 52) adopted this terminology for use in a stereotaxic instrument and it was adopted for mammals in general, especially in atlases. Also see horizontal plane (Henle, 1855).

Hypencephalon (Kupffer, 1893): Synonym for *hypothalamus* (Kuhlenbeck, 1927) for anamniote embryos; in German, *unterhirn*, pp. 51, 94 and Figs. E,F-17-19; also see His (1893b, Fig. 1-H) for human embryo.

Hypothalamus (His, 1893a): His introduced the term hypothalamus here, but included the preoptic region (Swanson, 1976b, pp. 229-235) of the *hypothalamus* (Kuhlenbeck, 1927) in the telencephalon (His, 1893b); pp. 159-162.

Hypothalamus (1893b): By this definition the preoptic region (Swanson, 1976b, pp. 229-235) of the *hypothalamus* (Kuhlenbeck, 1927) and *pars optica hypothalami* (His, 1893b) are within the telencephalon (His, 1893); also see His (1895, Figs. 17-20).

Hypothalamus (HY; Kuhlenbeck, 1927): The *ventral* (Schulze, 1893) *topographic division* of the *interbrain* (Baer, 1837): the *dorsal* (Barclay, 1803) *topographic division* is the *thalamus* (His, 1893a). The first adequate description of the *hypothalamus* as a layer of *gray matter* surrounding the lower half of the *third ventricle* (Galen, c173) was provided by Wharton (1656, see 1966 translation, p. 170); His (1893a, pp. 159-162) introduced the term but assigned the preoptic region (Swanson, 1976b, pp. 229-235) of the *hypothalamus* (Kuhlenbeck, 1927) to the telencephalon (His, 1893b). The definition here was introduced for vertebrates by Kuhlenbeck (1927, p. 67, Ch. 9); also see Christ (1969, p. 23), Nauta & Haymaker (1969, Tab. 4-1).

Independent effector (Parker, 1909): A non-neuronal *cell* (Hooke, 1665) producing a response like contraction or secretion without input from a *neuron* (Waldeyer, 1891); p. 56. See *effector* (Sherrington, 1906).

Inferior (Vicq d'Azyr, 1786): He defined it as below, or toward the plane on which the body is supported; pp. 51, 87; also see Standring (2008, p. xxii) and posterior (Aristotle).

Initial segment (Palay, 1964): Typically the narrowest segment of the *axon trunk*, just *distal* (Barclay, 1803) to the *axon hillock* (Schaffer, 1893), where action potentials are typically generated; p. 86; term also used by Herndon (1963, p. 170). Also see Palay et al. (1968) and Strong & Elwyn (1925, Fig. 136).

Inner (Galen, c173): Closer to the center of an object in the *body*; the opposite of *outer*; see Standring (2008, p. xxii). The dichotomy was used at least as far back as Galen in the second century; see, for example, translations by May (1968, pp. 711, 377) and Singer (1999, p. 131). Aristotle wrote in *De Partibus Animalium* of parts within the *body* and those placed on the outside; see translation by Ogle (1912, 674, 5-6).

Input: A *connection* to a *neuron* (Waldeyer, 1891), *neuron type* (Bota & Swanson, 2007), or *gray matter region* from another *neuron*, *neuron type*, or *gray matter region*. All such *nodes* can and generally do have multiple *inputs*.

Interbrain (IB; Baer, 1837): The *caudal* (Cleland, 1879) and *ventral* (Schulze, 1893) *topographic division* of the *forebrain* (Goette, 1873); the *rostral* (Schulze, 1893) and *dorsal* (Barclay, 1803) division is the *endbrain* (Kuhlenbeck, 1927). The *interbrain* in turn has two great *topographic divisions*, *dorsally* (Barclay, 1803) the *thalamus* (His, 1893a) and *ventrally* (Schulze, 1893) the *hypothalamus* (Kuhlenbeck, 1927). This basic division of the macrodissected adult human *brain* (Edwin Smith Surgical Papyrus, c1700 BC) has been recognized at least since Varolio (1573, p. 13, his *pars posterior medullae spinalis*), and it received its current name for vertebrates from Baer (1837, p. 107; in the original German, *Zwischenhirn*). This English form of *diencephalon* (Sharpey et al., 1867) has been used routinely, for example by Sharpey et al. (1867, p. 577), Johnston (1906, p. 25), Strong & Elwyn (1943, p. 12), and Williams & Warwick (1980, p. 953).

Internal: Synonym for *inner* (Galen, c173). The term was used by Aristotle in *De Partibus Animalium*; see translation by Ogle (1912, e.g., 685b-25); also see Barclay (1803, p. 116), Standring (2008, p. xxii).

Internodal connection: A *connection* between two *nodes*.

Interregional connection: A *connection* between two *gray matter regions*, as compared to an *intraregional connection*, which remains within a single *gray matter region*. It can be an interregional *macroconnection*, *mesoconnection*, or *microconnection*.

Interregional pathway: A *pathway* between two *gray matter regions*, as compared to an *intraregional pathway*, which remains within a single *gray matter region*. It can be an interregional *macropathway*, *mesopathway*, or *micropathway*.

Intranodal connection: For *macroconnections* (Thompson & Swanson, 2010) an *intraregional connection*, for *mesoconnections* (Thompson & Swanson, 2010) a *connection* that feeds back onto the *neuron type* (Bota & Swanson, 2007) that generates it (a connection from neuron type z to neuron type z), and for *microconnections* (Thompson & Swanson, 2010) a *connection* that feeds back onto the *neuron* (Waldeyer, 1891) that generates it (a connection from neuron z to neuron z).

Intranodal pathway: For *macropathways* an *intraregional pathway*, for *mesopathways* a *pathway* that feeds back onto the *neuron type* (Bota & Swanson, 2007) that generates it (a pathway from neuron type z to neuron type z), and for *micropathways* a *pathway* that feeds back onto the *neuron* (Waldeyer, 1891) that generates it (a connection from neuron z to neuron z).

Intraregional connection: A *connection* that arises and *terminates* within a particular *gray matter region*, as compared to an *interregional connection*, which extends between two *gray matter regions*. It can be an intraregional *mesoconnection* or *microconnection*.

Intraregional pathway: A *pathway* that arises and *terminates* within a particular *gray matter region*, as compared to an *interregional pathway*, which extends between two *gray matter regions*. It can be an intraregional *mesopathway* or *micropathway*.

Intrinsic connection: Often a synonym for *intraregional connection*, though its meaning can be vague and its use is thus discouraged.

Intrinsic pathway: Often a synonym for *intraregional pathway*, though its meaning can be vague and its use is thus discouraged.

Invertebrate brain (BRi): The most *rostral* (Schulze, 1893), largest, most differentiated *central ganglion* of a *central nerve cord* (or ganglia if multiple cords are involved); see Bullock & Horridge (1965, pp. 542-550). Cuvier (1800, lecture 11) explicitly discussed invertebrates and their brains without using the term itself.

Invertebrate nerves: *Nerves* (Herophilus, c335-280 BC) of the invertebrate *peripheral nervous system* (Meckel, 1817); see Bullock & Horridge (1965).

Invertebrate peripheral ganglia: *Ganglia* (Galen, c173) of the invertebrate *peripheral nervous system* (Meckel, 1817); see Bullock & Horridge (1965).

Ipsilateral: On the same side of the *body* in an animal with *bilateral symmetry*; see Standring (2008, p. xxii).

Lateral (Barclay, 1803): Away from the *median plane* (Henle, 1855) of the *body*, in the *frontal plane* (Henle, 1855); the opposite of *medial* (Schulze, 1893). Use of the term seems to go at least as far back as the second century and Galen (see, for example, translation by May, 1968, p. 701), but its formal use was introduced by Barclay (1803, pp. 121, 163), who paired it with mesial. Also see Brusca & Brusca (1990, Fig. 4-A).

Lateral ventricles (VL; Vesalius, 1543): The part of the *ventricles* (Hippocrates) in the right and left *endbrain* (Kuhlenbeck, 1927); they communicate with the unitary *third ventricle* (Galen, c173) through the *interventricular foramina* (one for each *lateral ventricle*). They correspond to the first and second ventricles, were known in macrodissected adult humans to Erasistratus (c310-c250 BC; see Clarke & O'Malley, 1996, p. 12), and were named such by Vesalius (1543; see translation by Singer, 1952, pp. 41, 68).

Leptomeninges: The *pia* (Galen, c192) and *arachnoid* (Blasius, 1666) considered together; see Standring (2008, p. 389).

Local connection: Often a synonym for *intraregional connection*, though its meaning can be vague and its use is thus discouraged.

Local tract: A *white matter tract* having a short course entirely within a *gray matter region*.

Longitudinal axis (Barclay, 1803): The oral-aboral axis (Schulze, 1893) of the *body* in all animals with a *nervous system* (Monro, 1783); term probably introduced by Barclay (1803, p. 117); also see Henle (1855, p. 1), Willmer (1990, p. 15). Other synonyms include *rostrocaudal axis*, *central axis*, *long axis*, *midsagittal axis*, *principal axis*, and *anteroposterior axis*, the latter being discouraged as especially ambiguous in comparative anatomy. The *longitudinal axis* is orthogonal to the *transverse axis* (Henle, 1855). The concept was clearly described by Aristotle in *De Partibus Animalium*, where he wrote that “a straight line as an axis has at the upper end the mouth, followed by the gullet, stomach, intestine, and excremental vent”; and that furthermore in some animals like humans, quadrupeds, crustacea, and

insects the axis is essentially straight, whereas at the other extreme in animals like the Cephalopods it can be highly curved and thus U-shaped; see translation by Ogle (1912, 685a-686b). Kuhlenbeck (1973, p. 111) provided a nice modern statement of the concept: “Three so-called *axial lines* [longitudinal or rostrocaudal, dorsoventral, and mediolateral] which can be conceived as geodesics and therefore not necessarily ‘straight’, provides an essentially *nonmetric* and *non-Euclidean* (*Euclidoid*), ameboid three-dimensional coordinate system (*German: ‘Bezungsmollusk’*) of anatomical space...”

Longitudinal plane (Henle, 1855): A plane of section passing through the *longitudinal axis* (Barclay, 1803) in animals with *radial symmetry*, dividing the *body* into roughly equal longitudinal halves; term alluded to by Henle (1855, p. 1). In animals with *bilateral symmetry* there are two orthogonal longitudinal planes, the *sagittal plane* (Henle, 1855) and *frontal plane* (Henle, 1855). A synonym is rostrocaudal plane.

Longitudinal tract: A *white matter tract* coursing essentially along the *longitudinal axis* (Barclay, 1803) of the *nervous system* (Monro, 1783); if a *longitudinal tract* crosses the *median plane* (Henle, 1855) in an animal with *bilateral symmetry*, the segment related to that plane is a *decussation*. The basically transverse and longitudinal organization of nervous system tracts was emphasized early on by Spencer (1881) and Cajal (1899-1904, vol. 1, p. 12), and more recently in the orthogon theory of Reisinger (1925, 1972).

Loop: Typically and logically it is synonymous with *closed chain*.

Macroconnection (Thompson & Swanson, 2010): A *connection* between two *gray matter regions*; p. 15239. At this level of analysis *gray matter regions* are treated as black box *nodes*, disregarding their composition of *neuron types* (Bota & Swanson, 2007) and *local connections*. That is, *macroconnections* are described to and from particular *gray matter regions*, disregarding *local connections* within the *gray matter regions*. In normal, healthy animals global *macroconnection* patterns are genetically hardwired.

Macropathway: A *pathway* between two *gray matter regions*.

Marginal ganglion: A *topographic division* with a small condensation of *neurons* (Waldeyer, 1891), outside of a *nerve ring*, in a *nerve net* of at least some active Coelenterate medusae, Ctenophora, and Echinoderms; see Bullock & Horridge (1965, Ch. 8), Cobb (1995).

Medial (Schulze, 1893): Toward the *median plane* (Henle, 1855) of the *body*, in the *frontal plane* (Henle, 1855); the opposite of *lateral* (Barclay, 1803); used thus by Schulze (1893, p. 6). Also see Brusca & Brusca (1990, p. 46).

Median plane (Henle, 1855): The *sagittal plane* (Henle, 1855) dividing a *body* into roughly equal right and left halves; term introduced by Henle (1855, p. 1); also see Standring (2008, Fig. 1). Synonyms include *midline* and *midsagittal plane*.

Mediolateral axis: In animals with *bilateral symmetry* an axis orthogonal to the *rostrocaudal axis* that lies in the *frontal plane* (Henle, 1855). It is unusual in having a right and left half reflected across the *median plane* (Henle, 1855); that is, for the right and left sides of the *body*, *medial* (Schulze, 1893) is toward the *median plane* and *lateral* (Barclay, 1803) is toward the right or left edge of the *body*. A synonym is *right-left axis*; see Kuhlenbeck (1973, p. 112).

- Medulla (MY; Winslow, 1733):** The *topographic division* of the *cerebrospinal axis* (Meckel, 1817) between *pons* (Haller, 1747) and *spinal cord* (Galen, c162-c166). It was clearly described and illustrated for macrodissected adult humans by Piccolomini (1586, pp. 265, 269; his *intracranial medulla oblongata*), while the term *medulla* was used by Winslow (1733, Sect. X, p. 42) and Haller (1747, see translation by Mihles, 1754, pp. 287, 286), and more recently in the classic textbooks of for example Mettler (1948, p. 76) and Carpenter (1976, p. 60). Synonyms include *medulla oblongata* (Bartholin, 1651), *spinal bulb* (Chaussier, 1807), *bulb* (Chaussier, 1807), *afterbrain* (Baer, 1837), *metencephalon* (Sharpey et al., 1867), *myelencephalon* (Huxley, 1871), *epencephalon* (Mihailkovics, 1877).
- Medulla oblongata** (Bartholin, 1651): Synonym for *medulla* (Winslow, 1733); probably introduced by Bartholin (1651, p. 317) and clearly used thus by Collins (1685, Tab. 48-M).
- Medulla spinalis** (Hippocrates): Latin form of *spinal cord* (Galen, c1620-c166), introduced (in Greek) by Hippocrates in *On the Sacred Disease* and *Fleshes*, see translations by Adams (1972, pp. 234, 309) and Potter (1995, p. 139), respectively, and May (1968, p. 575).
- Meninges (MEN; Edwin Smith Surgical Papyrus, c1700 BC):** The connective tissue coverings of the *nervous system* (Monro, 1783) that in mammals are divided concentrically from outside to inside into *dura* (Galen, c177), *arachnoid* (Blasius, 1666), and *pia* (Galen, c192), which often extends along blood vessels into the *central nervous system* (Meckel, 1817). A term equivalent to the Greek *meninx*—membrane, in the present context a fibrous membrane around the *brain* (Edwin Smith Surgical Papyrus, c1700 BC)—was used to describe a human head wound in the Edwin Smith Surgical Papyrus, a c1700 BC copy of a manuscript composed c3200 BC; see Breasted (1930, pp. 65, 167, 171-172), Clarke & O'Malley (1996, p. 384), Allen (2005, p. 75).
- Mesencephalon** (Sharpey et al., 1867): Latin form of *midbrain* (Baer, 1837); it was introduced for macrodissected adult humans by Sharpey et al. (1867, p. 577), who also introduced the English, “midbrain”.
- Mesoconnection (Thompson & Swanson, 2010):** A *connection* between two *neuron types* (Bota & Swanson, 2007), or between a *neuron type* (Bota & Swanson, 2007) and another cell type like muscle or gland cells; p. 15239. At this level of analysis all *axon connections* from (*outputs* of) a particular *neuron type* (Bota & Swanson, 2007) are arranged in terms of a stereotyped collateralization (branching) pattern of the *axon trunks* of the *neuron type* (Bota & Swanson, 2007), with individual *axon collaterals* innervating specific *neuron types* (Bota & Swanson, 2007)—the individual *axon connections* of the *neuron type*. At this level of analysis *mesoconnections* are established by *synapses* (Foster & Sherrington, 1897). In normal, healthy animals global *mesoconnection* patterns are genetically hardwired.
- Mesopathway:** A *pathway* between two *neuron types* (Bota & Swanson, 2007).
- Metencephalon** (Sharpey et al., 1867): Original Latin form of *afterbrain* (Baer, 1837), that is, the *medulla* (Winslow, 1733); see p. 577. Also see *metencephalon* (Huxley, 1871).
- Metencephalon** (Huxley, 1871): Synonym for *epencephalon* (Sharpey et al., 1867) and thus *hindbrain* (Baer, 1837); p. 60. Wilder (1899, p. 573) regarded the shifting of *afterbrain* (Baer, 1837) and thus *metencephalon* (Sharpey et al., 1867) from the last

position to the penultimate position, and replacing metencephalon (Sharpey et al., 1867) with myelencephalon (Huxley, 1871)—which had previously referred to the *cerebrospinal axis* (Meckel, 1817) as a whole: myelencephalon (Owen, 1868)—as “constituting a violation of scientific ethics that merits the severest reprobation”! The situation is perfectly illustrated by comparing Gehuchten (1893, Figs. 32, 33) with Gehuchen (1906, Fig. 14)—before and after His (1895, Fig. 20 and p. 162).

Metencephalon (Williams & Warwick, 1980): Synonym for macrodissected adult human *pons* (Haller, 1747); p. 864.

Microconnection (Thompson & Swanson, 2010): A *connection* between two individual *neurons* (Waldeyer, 1891), or between one *neuron* and another cell like a muscle or gland cell; p. 15239. At this level of analysis *connections* are established by *synapses* (Foster & Sherrington, 1897). In normal, healthy animals qualitative aspects of *microconnection* patterns are genetically hardwired but their quantitative features can be modified by learning, stress, and a variety of other factors.

Micropathway: A *pathway* between two *neurons* (Waldeyer, 1891).

Midbrain (MB; Baer, 1837): The middle of the three primary brain vesicles of the vertebrate *neural tube* (Baer, 1837) that develops into the adult *midbrain* (Baer, 1837), a *topographic division* between *forebrain* (Goette, 1873) and *rhombicbrain* (His, 1893b). Malpighi (1675; see translation by Adelman, 1966, p. 1003) identified the cristate vesicle in the chick *neural tube*, and Baer named it the midbrain vesicle for embryonic vertebrates (1837, p. 106; in the original German, *mittlere Hirnbläachen*). Baer also named the corresponding adult structure the *midbrain* (1837, p. 107; in the original German, *Mittelhirn*). A synonym is the Latin mesencephalon (Sharpey et al., 1867).

Midline (Aristotle): Synonym for *median plane* (Henle, 1855). Aristotle (*Historia Animalium*; see translation by Thompson, 1910, 491b-5) used (the Greek equivalent of) the term for macrodissected adult humans, translated “middle line”. Also see Brusca & Brusca (1990, p. 46).

Midsagittal plane: Synonym for *median plane* (Henle, 1855); see Brusca & Brusca (1990, p. 46).

Mixed synapse: A *synapse* (Foster & Sherrington, 1897) that combines the features of both the *chemical synapse* and the *electrical synapse*; see Peters et al. (1991, pp. 207-210).

Motif: A recurring pattern of *connections*; that is, a unit *chain* from which more complex *neural networks* are constructed. A consensus motif is a recurring pattern of *connections* in a *network* of a specific type.

Myelencephalon (Owen, 1868): Synonym for vertebrate *central nervous system* (Meckel, 1817); pp. 266-268.

Myelencephalon (Huxley, 1871): Synonym for *medulla* (Winslow, 1733), pp. 59-60. Also see metencephalon (Huxley, 1871).

Myelin sheath: A covering of *axons* (Kölliker, 1896)—and occasionally *dendrites* (His, 1889) or even *cell bodies* (Deiters, 1865)—above a particular diameter characteristic for each species that speeds up action potential conduction velocity and is formed by types of *glia* (Virchow, 1846): oligodendrocytes in the vertebrate *central nervous system* (Meckel, 1817), and Schwann cells in the vertebrate *peripheral nervous system* (Meckel, 1817); see Williams (1995, pp. 951-954), Toesca (1996). The *myelin*

sheath was probably discovered by Remak (1837) who described a very thin-walled tube around his primitive band, the *axon*; see Van der Loos (1967, p. 19).

Myelinated axon: An *axon* (Kölliker, 1896) with a *myelin sheath*, which is formed by types of *glia* (Virchow, 1846): oligodendrocytes in the vertebrate *central nervous system* (Meckel, 1817), and Schwann cells in the vertebrate *peripheral nervous system* (Meckel, 1817). *Axons* above a threshold diameter characteristic of particular species become myelinated, thus forming the set of thicker *axons*; see Williams (1995, pp. 951-954). The *myelinated axon* was probably discovered by Remak (1837) who described a primitive band—the *axon*—within a very thin-walled tube (see Van der Loos, 1967, p. 19).

Nerve cell: Synonym for *neuron* (Waldeyer, 1891). The term was used by Kölliker (1852; see Shepherd, 1991, p. 35); also see Peters et al. (1991, p. 11).

Nerve fiber (Ehrenberg, 1833): An *unmyelinated axon* or a *myelinated axon*; literally accurate for the *peripheral nervous system*, but often applied (ambiguously) to the *central nervous system* as well. In the second century Galen (see translations by Duckworth, 1962, p. 254; Clarke, 1968, p. 124) recognized the fibrous nature of *nerves* (Herophilus, c335-280 BC). Leeuwenhoek (1718; see Van der Loos, 1967, pp. 10-16) identified the *nerve fiber* itself as the ultimate structure of *nerves* and called it a vessel, whereas Ehrenberg (1833, pp. 453-456) called it a *nerve fiber*.

Nerve net: A *topographic division* that is a longitudinally arranged *nervous system* (Monro, 1783) with *radial symmetry* and relatively evenly and diffusely distributed *neurons* (Waldeyer, 1891), characteristic of Coelenterates, Ctenophores, Hemichordates, Pogonophores, and adult Echinoderms. While small *neuron condensations* (called *marginal ganglia*) and circular zones (called *nerve rings*) with a higher concentration of *neurons* and *neuron extensions* can be present, *nerves* (Herophilus, c335-280 BC) are not clearly differentiated, and nothing like a *central nervous system* (Meckel, 1817) is present; see Bullock & Horridge (1965, p. 12 & Ch. 8), Cobb (1995). It is thus a *nervous system* with no clear *topographic divisions*—a *divisionless nervous system*. The *nervous system* of hydra (a Coelenterate) is an example of a relatively simple diffuse *nerve net*, whereas the *terminal plexuses* in the wall of the mammalian *digestive system* can be viewed as analogous to a relatively differentiated *nerve net*.

Nerve ring: A *topographic division* consisting of a circular zone of a *nerve net* with a higher concentration of *neurons* (Waldeyer, 1891) and *neuron extensions*; see Bullock & Horridge (1965, p. 475), Cobb (1995, p. 411).

Nerve terminal (Cajal, 1899): Synonym for *axon terminal* (Barker, 1899); term used for Golgi material by Cajal (1899, p. 67).

Nerves (n; Herophilus, c335-280 BC): A *nerve* is a *topographic division* with macroscopically recognizable bundles of *axons* (Kölliker, 1896), or *white matter tracts*, in the *peripheral nervous system* (Meckel, 1817) of invertebrates and vertebrates. A *nerve* can have a number of structural differentiations like roots, trunk, and branches, and can have a *peripheral ganglion* associated with it. When a series of *ganglia* is associated with a *white matter tract*, it is referred to as a *peripheral nerve cord* in the *peripheral nervous system* (Meckel, 1817), a *central nerve cord* in the *central nervous system* (Meckel, 1817) of invertebrates, or a *radial nerve cord* in a *nerve net* of invertebrates. Herophilus (c335-c280 BC), the founder of human

anatomy, is credited with discovering *nerves*, including most of the *cranial nerves* (Longet, 1842) and *spinal nerves* (Camper, 1760) by distinguishing them from arteries; see Solmsen (1961, p. 185), von Staden (1989, pp. 250-252), and Longrigg (1993, pp. 192, 211).

Nervous system (Willis, 1664): Willis's use of the term in his comparative anatomical research was synonymous with *peripheral nervous system* (Meckel, 1817); see Willis translation by Pordage (1681, p. 125ff.).

Nervous system (NS; Monro, 1783): One system in the set of *body systems*. According to Bullock & Horridge, "A nervous system may be defined as an organized constellation of cells (neurons) specialized for the repeated conduction of an excited state from receptor sites or from other neurons to effectors or to other neurons." (1965, p. 6; also see Brusca & Brusca, 1990, p. 81). The structural arrangement or organization of *connections* between these *neurons* (Waldeyer, 1891), or more generally *nodes*, forms a *neural network* called the *wiring diagram* of the *nervous system* (Monro, 1783). In many animals the *nervous system* also contains *glia* (Virchow, 1846), and is invaded by the *circulatory system*. It is the chief system that integrates adjustments and reactions of the organism to internal and environmental conditions; see Dorland's (2003). In all animals the *nervous system* probably differentiates from the embryonic ectodermal layer; see Brusca & Brusca (1990, p. 103). The *nervous system* as such was probably first recognized (in writings that survive) by Rufus of Ephesus (fl. c100; see Clarke & O'Malley, 1996, p. 13); Monro (1783, p. 1) introduced the term as now used.

Nervous system parts: Objects in the *nervous system* (Monro, 1783) above the level of *neuron types* (Bota & Swanson, 2007).

Network: Short form of *neural network*.

Neural network: The structural arrangement of all *neurons* (Waldeyer, 1891) and their *connections* in a *nervous system* (Monro, 1783). A *neural network* has a set of *nodes* and the *connections* between them and other parts of the *body* like muscles and glands. A complete *neural network* can be distinguished from a *neural subnetwork*, which is an arbitrary subset of the complete *neural network*, often distinguished on functional grounds.

Neural subnetwork: An arbitrary subset of a complete *neural network*, often distinguished on functional grounds. A closely related term is *neural subsystem*.

Neural subsystem: A subset of the complete *nervous system* (Monro, 1783) defined on functional grounds; for example, the visual system or the somatic motor system. A closely related term is *neural subnetwork*, but formally a *neural subsystem* would include objects other than *neurons* (Waldeyer, 1891).

Neural tube (NT; Baer, 1837): The embryonic primordium of the adult *cerebrospinal axis* (Meckel, 1817) that is formed from the *neural plate* (Stricker, 1860) by the process of neurulation; see Nieuwenhuys et al. (2008, pp. 7-9). Galen probably glimpsed the macrodissected mammalian *neural tube* (see Adelman, 1966, p. 747) and Baer (1837, p. 59) introduced the term for macrodissected vertebrate embryos. Varolio (1573, see English translation, 1969, p. 34) observed three transparent globules (*tres globulos transparentes* in Latin) in the 9-day macrodissected chick embryo and Baer (1837, pp. 106, 107) called them the three primary brain vesicles (*primären Hirnbläschen* in German and *Vesiculae cerebrales* in Latin): anterior or

forebrain primary vesicle (*vordere Bläschen* in German), middle or midbrain primary vesicle (*mittleres Bläschen* in German), and posterior or hindbrain primary vesicle (*hinteres Bläschen* in German). He also observed that they develop into 5 vesicles going on to form the 5 morphological elements or basic parts of the adult *vertebrate brain* (Cuvier, 1800): *Vorderhirn*, *Zwischenhirn*, *Mittelhirn*, *Hinterhirn*, and *Nachhirn* in the original German. Sharpey et al. (1867, p. 577) gave the English and Latin equivalents of these 5 parts: secondary forebrain or prosencephalon, interbrain or diencephalon, midbrain or mesencephalon, secondary hindbrain or epencephalon, and afterbrain or metencephalon. In the *Foundational Model of Connectivity* these 5 parts are called *endbrain* (Kuhlenbeck, 1927) or telencephalon (Kuhlenbeck, 1927), *interbrain* (Baer, 1837) or diencephalon (Sharpey et al., 1867), *midbrain* (Baer, 1837) or mesencephalon (Sharpey et al., 1867), *hindbrain* (Baer, 1837) or epencephalon (Sharpey et al., 1867), and afterbrain (Sharpey et al., 1967), metencephalon (Sharpey et al., 1867) or *medulla* (Winslow, 1733). The *hindbrain* (Baer, 1837) consists of *cerebellum* (Aristotle) and *pons* (Haller, 1747).

Neural plate (NPL; Stricker, 1860): The medial differentiation of the embryonic vertebrate ectodermal layer, *dorsal* (Barclay, 1803) to the notochord, that goes on by the process of neurulation to form the *neural tube* (Baer, 1837); observed in macrodissected chick embryos by Malpighi (1673, Tab. I), and named thus by Stricker (1860, p. 474) based on toad embryo histology.

Neurite: Term often used now for a *neuron extension* when its identity as *axon* (Kölliker, 1896), *dendrite* (His, 1889), or *amacrine extension* is unclear; see Peters et al. (1976, p. 9; 1991, p. 10). The term was originally coined to refer to the *axon* by Rauber (1894).

Neuron (Waldeyer, 1891): For the *nervous system* (Monro, 1783), the basic structural and functional unit at the level of *cells* (Hooke, 1665). The *connections* of *neurons* form the *connectome* and *wiring diagram*. Probably discovered microscopically by Dutrochet (1824; Pl. 2, fig. 20) in unfixed molluscan *ganglia* (Galen, c173) and named thus by Waldeyer (1891, p. 1352); also see Peters et al. (1991, p. 11).

Neuron extension: A thin cytoplasmic projection from the *cell body* (Deiters, 1865) that may be *axon* (Kölliker, 1896), *dendrite* (His, 1889), or *amacrine extension*. Synonym is neuron process.

Neuron population (POP; Burns, 2001): An arbitrarily defined set of *neurons* (Waldeyer, 1891) that may or may not correspond exactly to a specific *gray matter region* or *neuron type* (Bota & Swanson, 2007). For example, a *neuron population* is formed by a subset of the individual *neurons* that together constitute a *neuron type*. In contrast, however, all *neurons* within an anterograde pathway tracer injection *site* that spreads to involve multiple adjacent *gray matter regions*, or an irregular extent within a single *gray matter region*, form the *neuron population* associated with that injection *site*. Another example of this type would be all *neurons* within multiple *gray matter regions* that *project* to a single *gray matter region*—as demonstrated, for example, by a retrograde pathway tracer injection *site*. A third example would be all *neurons* in the *hypothalamus* (Kuhlenbeck, 1927) that express the corticotropin-releasing hormone (CRH) gene following hypovolemic stress, as demonstrated by in situ hybridization. In general, a *site* contains a *neuron population*. Term thus defined was introduced by Burns (2001, p. 1201 and Fig. 10).

Neuron process: Synonym for *neuron extension*. Use of neuron process is discouraged because process could easily be misinterpreted to mean an action or series of actions; see Oxford English Dictionary (1989). Purkinje (1838, e.g., Fig. 16) used the term process (*Fortsätze* in the original German) for extensions of neuron *cell bodies* (*Deiters, 1865*)—which he referred to as *gangliöse körperchen*, ganglionic bodies; see Barker (1899, p. 66), Jones & Cowan (1983, p. 290). “Process” has been used in anatomy to describe a protuberance or projection since at least the 16th century; see Oxford English Dictionary (1989, def. 13).

Neuron type (Bota & Swanson, 2007): For purposes of *wiring diagrams*, *neuron types* are defined and classified primarily by their *connections* and, secondarily by their location, shape, and size. *Neurons* (*Waldeyer, 1991*) can be placed in a seven-level taxonomic hierarchy, with *neuron types* occupying a level equivalent to species in animal taxonomy. Formally, a *neuron type* is defined as a distinct cluster in polythetic parametric space, with the main parameter being connections, secondary parameters being location, shape, and size, and tertiary parameters also helpful. An example of a *neuron type* is blue cone, of the *neuron group* cone, of the *neuron class* photoreceptor, of the *neuron category* visual, of the *neuron division* sensory, of the *cell type* neuron, with no known *neuron varieties* of this *neuron type*, at least in rat (see Bota & Swanson, 2007). *Neuron types* can consist of a single identified *neuron* (most common for invertebrates) or a set of *neurons* sharing the same parametric space. *Neuron types* were first recognized by Purkinje (1838) and first classified by Golgi (1873).

Neuropil (nep; Waldeyer, 1891): The *gray matter* (*Meckel, 1817*) compartment exclusive of *cell bodies* (*Deiters, 1865*) and *vascular cells*, thus consisting of the cytoplasmic extensions of *neurons* (*Waldeyer, 1891*) and *glia* (*Virchow, 1846*), including *synapses* (*Foster & Sherrington, 1897*). It was discovered histologically in spiders by Leydig (1855, p. 413), who called it the *Punktsubstanz*, or dotted substance in English; Waldeyer first used the term (1891, p. 1354). Also see Bullock & Horridge (1965, pp. 16, 27, 54), Peters et al. (1991, Ch. 11).

Node: The site of *origin* or of *termination* of a *connection* at the level of a *gray matter region* (macronode), *neuron type* (*Bota & Swanson, 2007*) (mesonode), or individual *neuron* (*Waldeyer, 1891*) (micronode). Nodal masses of *gray matter* were described systematically as long ago as Meynert (1872, p. 654).

Nomenclature: In the *Foundational Model of Connectivity* a set of terms that refers to a *nervous system part*.

Nucleus: See *gray matter nucleus* and *cell nucleus* (*Brown, 1833*).

Open chain: A series of *connections* that do not lead back to a *node* in the series; when a connection leads back to a *node* in the series there is a *closed chain*.

Oral-aboral axis (*Schulze, 1893*): Synonym for *rostrocaudal axis*; often preferred in the comparative anatomy of invertebrates; p. 5. Also see Willmer (1990, p. 15).

Origin: The *neuron* (*Waldeyer, 1891*), *neuron type* (*Bota & Swanson, 2007*), or *gray matter region* that generates a *connection* or *output*; see Herrick (1915, p. 108).

Outer (Galen, c173): Away from the center of an object in the *body*; the opposite of *inner*; see Standring (2008, p. xxii). The dichotomy was used at least as far back as Galen in the second century; see, for example, translations by May (1968, pp. 711, 377) and Singer (1999, p. 131). Aristotle wrote in *De Partibus Animalium* of parts

within the *body* and those placed on the outside; see translation of Ogle (1912, 674, 5-6).

Output: A *connection* from a *neuron* (Waldeyer, 1891), *neuron type* (Bota & Swanson, 2007), or *gray matter region* to another *neuron*, *neuron type*, or *gray matter region*. All such *nodes* can have multiple *outputs*.

Pachymeninges: Synonym for *dura* (Galen, c177); another form is *pachymeninx*; see Standring (2008, p. 389).

Pallium (Burdach, 1822): Synonym for *cerebral cortex* (Bauhin, 1605). Used first by Burdach for macrodissected adult humans (1822, p. 13), and by many others since, including His (1895, p. 85), Nauta & Feirtag (1986, p. 45). In Latin “pallium” refers to a mantle, cloak, or blanket (Oxford Latin Dictionary, 1996).

Parasympathetic ganglia (PSY; Kuntz, 1934): Synonym for *terminal ganglia* (Gaskell, 1886); apparently named thus by Kuntz (1934, p. 126).

Paravertebral ganglia (GPAS): A *topographic division* of *autonomic ganglia* (Langley, 1900) associated with the *sympathetic trunk* (Winslow, 1733) and branches arising directly from it, including the *carotid ganglion* (Lobstein, 1831), *sympathetic trunk ganglia* (Winslow, 1733), and *intermediate ganglia*. Falloppio (1561; see Johnstone, 1765, p. 177) is credited with discovering them in macrodissected adult humans, for contemporary terminology see Durward (1951, p. 1126).

Paravertebral nerves (PAN): A *topographic division* of *autonomic nerves* (Langley, 1898) that macroscopically appear to arise from *paravertebral ganglia* and/or the *sympathetic trunk* (Winslow, 1733).

Parencephalon (Aristotle): Synonym for *cerebellum* (Aristotle). This is the original term, derived from the Greek, used by Aristotle in *Historia Animalium* for the *cerebellum*; see Longrigg (1993, p. 212) and Clarke & O’Malley (1996, pp. 629-630).

Parencephalon (Kupffer, 1893): Synonym for *thalamus* (His, 1893a); in the original German, *Nebenhirn*, p. 61 and Fig. F-p.

Parent axon: Synonym for *axon trunk*. Galen in the second century used the term parent for macrodissected *nerves* (Herophilus, c335-280 BC) as a whole; see translation by Duckworth (1962, p. 203).

Pars optica hypothalami (His, 1893b): Basically it consists of the anterior and tuberal regions (Swanson, 1987, p. 2) of the *hypothalamus* (Kuhlenbeck, 1927). It is part of the telencephalon (His, 1893b); see His (1893b, p. 178; 1895, p. 158).

Partial correspondence: In neuroanatomy many terms do not fit exactly into any part of the structural hierarchy. Such terms *partly correspond* to a *standard term* somewhere in the hierarchy, and should be defined (described) with reference to the immediately higher *standard term* within which it completely fits. The concept of a *party corresponding* term is important because such a term generally does not share all of the properties of any particular *reference term* and thus cannot fit exactly anywhere within the hierarchy as such—it does not have a strict *PART-OF* relationship with any component of the *Foundational Model of Connectivity* hierarchy. This is because *gray matter regions* and *neuron types* (Bota & Swanson, 2007) generally are not homogeneous; instead, they have defining and differentiable features in parameter space that occur in gradients. As a result different *sites* within a *gray matter region* generally have different features and thus different *microconnections*.

Partly corresponds: Verb form of *partial correspondence*; partly corresponding is another form.

Passing synapse: English form of “synapse en passant”.

Pathway: The component of a *connection* that is demonstrated in a specific tracing experiment or analysis. This definition is specific to the *Foundational Model of Connectivity* where it is useful for description to have terms distinguishing between *pathway* and *connection*. As with *connections*, there can be *macropathways*, *mesopathways*, and *micropathways*. Other usages of the word *pathway* are common, especially as a synonym for *connection* or *projection*. The term *path* or *pathway* was used for a *route* of transmission in the *nervous system* (Monro, 1783) as long ago as Galen (c173); see translations by May (1968, pp. 401-402) and Clarke & O’Malley, (1996, p. 630).

Perikaryon (Foster & Sherrington, 1897): The *cell body* (Deiters, 1865) without the *cell nucleus* (Brown, 1833); p. 928, also see Peters et al. (1991, p. 14).

Peripheral (Barclay, 1803): Toward the surface of the *body*. Barclay (1803, pp. 120-121, 164) introduced a formal distinction between *central* (Barclay, 1803) and *peripheral*.

Peripheral ganglia (GPR): A *peripheral ganglion* is a macroscopic aggregation of *neurons* (Waldeyer, (1891), that is, a *gray matter region*, in the *peripheral nervous system* (Meckel, 1817) of invertebrates and vertebrates; see Bullock & Horridge (1965, p. 51), also see *ganglion* (Galen, c173).

Peripheral longitudinal communicating branch: The segment of a *peripheral nerve cord trunk* between two *peripheral ganglia* associated with the corresponding *peripheral nerve cord* as a whole.

Peripheral nerve cord: A *topographic division* that has a longitudinal *peripheral nerve cord trunk* (equivalent to a *white matter tract*) with a series of more or less regularly spaced *peripheral ganglia* along its course, and a trunk segment between two adjacent ganglia called a *peripheral longitudinal communicating branch*. The prototypical vertebrate example is the *sympathetic trunk* (Winslow, 1733) with its *sympathetic trunk ganglia* (Winslow, 1733)—together the sympathetic cord.

Peripheral nerve cord trunk: The equivalent of a *white matter tract* for a *peripheral nerve cord*, with *peripheral ganglia* distributed along its length.

Peripheral nervous system (PNS; Meckel, 1817): In bilateral animals, a *topographic division* with condensations of the *nervous system* (Monro, 1783) consisting of *nerves* (Herophilus, c335-280 BC) and *ganglia* (Galen, c173). When a *PNS* is present, its obligate companion *topographic division* is a *central nervous system* (Meckel, 1817). There is no known isolated part of the *PNS* that does not have a *connection* to the rest of the *nervous system*; see Bullock & Horridge (1965, pp. 9-14). While the *nerves* were discovered by Herophilus (335-280 BC; see Solmsen, 1961, p. 185; von Staden, 1989, pp. 250-252), the term *peripheral nervous system* as currently understood was first used by Meckel (1817; see English translation 1832, p. 153).

Pia (PI; Galen, c192): The innermost of the *meninges* (Edwin Smith Surgical Papyrus, c1700 BC), closely covering the *brain* (Edwin Smith Surgical Papyrus, c1700 BC) and *spinal cord* (Galen, c162-c166) and consisting of reticular, elastic, and collagenous fibers. It is histologically similar to the *arachnoid* (Blasius, 1666), and

the two are often considered together as the leptomeninges; see Dorland's (2003), Standring (2008, p. 389). The *pia* was apparently known to Hippocrates in *Places in Man* (see translation by Potter, 1955, p. 23) and was described and named such by Galen (c192; see translation by Duckworth, 1962, p. 6).

Pia mater (Ali ibn' ul-Abbas, d994): Synonym for *pia* (Galen, c192); for naming see Wiberg (1914, p. 86-89).

Plexus (plx; Galen, c192): A general term for a group of interconnecting *neurons* (Waldeyer, 1891) or *nerve* (Herophilus, c335-280 BC) components that may be a sheet of interwoven fibers or a coarse mesh of communicating *nerves*, without or with neuron *cell bodies* (Deiters, 1865), including *ganglia* (Galen, c173); see Oxford English Dictionary, 1989; Bullock & Horridge, 1965, p. 1606). Examples include *nerve nets*, *prevertebral plexuses*, and *spinal nerve plexuses* (with *postplexus spinal nerves* distal to them). Galen (c192; see translation by Duckworth, 1962, p. 243) used the term *plexus* in describing the macrodissected adult mammalian *brachial plexus* (Camper, 1760).

Pons (P; Haller, 1747): The *ventral* (Schulze, 1893) *topographic division* of the *hindbrain* (Baer, 1837); the *dorsal* (Barclay, 1803) *topographic division* is the *cerebellum* (Aristotle). The *middle cerebellar peduncle* on the periphery of the macrodissected adult human *pons* ("bridge" in English) was identified by Varolio (1573, Fig. I, f. 17v; also see Clarke & O'Malley 1996, pp. 634-635, 821). Collins (1685, see Tab. 48-L, his *caudex of medulla oblongata*) identified the *pons* as defined here, and Haller (1747, see translation by Mihles, 1754, pp. 287, 296) provided the term itself. *Pons Varolii* (Bell, 1802) is a synonym.

Pons Varolii (Bell, 1802): Synonym for macrodissected adult human *pons* (Haller, 1747); see Pls. VII-8, IX-N, X-b.

Posterior (Aristotle): *Caudal* (Cleland, 1879) in relation to the *longitudinal axis* (Barclay, 1803); commonly used in this way for comparative anatomy, as was the case for Aristotle in *De Partibus Animalium*; see, for example, translation of Ogle (1912, 684b-25). Vicq d'Azyr (1786, pp. 51, 58) first clearly defined the term as behind or opposite the face, corresponding in most vertebrates to *caudal*, and in humans to *dorsal* (Barclay, 1803) or *posterior* (Galen, c177). Discarding the ambiguous terms *anterior* and *posterior* has been urged since at least 1880 (Spitzka, 1880, p. 75); also see *anterior* (Aristotle), Standring (2008, Fig. 1).

Posterior (Galen, c177): *Dorsal* (Barclay, 1803) in relation to the *longitudinal axis* (Barclay, 1803); commonly used in this way for human and other primate anatomy, as was the case for Galen; see translations of Singer (1999, p. 129) and Duckworth (1962, pp. 229, 231). Also see *anterior* (Aristotle), Standring (2008, Fig. 1).

Postplexus spinal nerves: *Spinal nerves* (Camper, 1760) distal to the *spinal nerve plexuses*. The major ones were described for macrodissected animals except human in the second century by Galen; see translations of Duckworth (1962, pp. 230-264) and May (1968, pp. 598-603).

Postsynaptic: Referring to the *postsynaptic compartment* (De Camilli et al., 2001).

Postsynaptic compartment (De Camilli et al., 2001): The part of a *chemical synapse* that binds neurotransmitters released from the *presynaptic compartment* (De Camilli et al., 2001) into the *synaptic cleft*; see pp. 112-113.

Presynaptic: Referring to the *presynaptic compartment* (De Camilli et al., 2001).

Presynaptic compartment (De Camilli et al., 2001): The part of a *chemical synapse* that releases neurotransmitter into the *synaptic cleft* for action on the *postsynaptic compartment* (De Camilli et al., 2001); see p. 93 ff.

Prevertebral ganglia (GPRS; Gaskell, 1886): A *topographic division* of *autonomic ganglia* (Langley, 1900) associated with the *prevertebral plexuses*. Galen in the second century saw at least part of them—the *celiac ganglion* (Walter, 1783)—in macrodissected adult animals except humans; see translations by Duckworth (1962, pp. 217-218), May (1968, pp. 695-696, 711), Smith (1971, p. 179). Gaskell (1886, p. 3) named them for vertebrates based on structure-function criteria.

Prevertebral nerves (PNE): A *topographic division* of *autonomic nerves* (Langley, 1898) that macroscopically appear to arise from *prevertebral ganglia* (Gaskell, 1886) and/or *prevertebral plexuses*, and typically end in *terminal plexuses* and/or *terminal ganglia* (Gaskell, 1886).

Prevertebral plexuses (PVE): A *topographic division* of *autonomic nerves* (Langley, 1898) that form an interconnected series of more or less distinguishable perivascular thoracic, abdominal, and pelvic *plexuses* (Galen, c192) of small *communicating branches* (Winslow, 1733) or anastomotic nerve fiber bundles. Their functional composition is complex with varying mixtures of postganglionic sympathetic *axons* (Kölliker, 1896) from *paravertebral nerves*, preganglionic parasympathetic *axons*, visceral afferent fibers, and *prevertebral ganglia* (Gaskell, 1886) that are mostly sympathetic—except in the *inferior hypogastric plexus* where there is a mixture of sympathetic and parasympathetic *neurons* (Waldeyer, 1891); see Durward (1951, pp. 1120, 1128, 1138) for name and Williams & Warwick (1980, pp. 1132-1137).

Process: Can be a short form of neuron process (Purkinje, 1838), a *neuron extension*.

Projection: Synonym for *connection*.

Projections: Synonym for *connections*.

Prosencephalon (Sharpey et al., 1867): Original Latin form of forebrain (Baer, 1837), the *endbrain* (Kuhlenbeck, 1927); p. 577.

Prosencephalon (Mihalkovics, 1877): Original Latin form of macrodissected adult vertebrate *forebrain* (Goette, 1873).

Proximal (Barclay, 1803): Toward the origin of an object like a tentacle, limb, or nerve; the opposite of *distal* (Barclay, 1803). Introduced by Barclay (1803, pp. 124-125, 164), also see Standring (2008, p. xxii).

Radial nerve cord: A *topographic division* that is a differentiated linear zone of the *nerve net* in Echinoderms with periodic small *ganglia* (Galen, c173) along its length, and extending into each of the (most commonly five) arms from the *circumoral nerve ring*. There is no convincing evidence that the Echinoderm *nervous system* (Monro, 1783) is divided into *central nervous system* (Meckel, 1817) and *peripheral nervous system* (Meckel, 1817); see Cobb (1995, p. 411). A cord segment between two adjacent ganglia is called a *longitudinal communicating branch*.

Radial symmetry: Symmetry around the *longitudinal axis* (Barclay, 1803) of the *body*; see Willmer (1990, p. 15), Brusca & Brusca (1990, p. 44).

Reference term: Synonym for *standard term*. It is not preferred because of possible confusion with literature references.

Region: Shortened form of *gray matter region*, though other definitions are found in the literature.

Rhombencephalon (His, 1893b): Latin synonym for *rhombicbrain* (His, 1893b); p. 173.

Rhombicbrain (RB; His, 1893b): The *caudal* (Cleland, 1879) of the three primary brain vesicles—the primary hindbrain vesicle (Baer, 1837)—of the vertebrate *neural tube* (Baer, 1837) develops into the adult *topographic division*, the *rhombicbrain*. The latter contains the *hindbrain* (Baer, 1837) or synonymous secondary hindbrain (Sharpey et al., 1867)—which is the *cerebellum* (Aristotle) and *pons* (Haller, 1747)—combined with the *medulla* (Winslow, 1733) or afterbrain (Baer, 1837). His introduced *rhombicbrain* for macrodissected adult vertebrates (in the original German, *Rautenhirn*, p. 173), and Herrick (1915, p. 121), for example, applied the English form used here. Synonyms include rhombencephalon (His, 1893b), epencephalon (Owen, 1868), hindbrain (Carpenter, 1976).

Rostral (Schulze, 1893): Toward the mouth along the *longitudinal axis* (Barclay, 1803) of the *body*; the opposite of *caudal* (Cleland, 1879); p. 6. Originally, toward the beak of a ship's prow (*rostrum*). In the BNA, His (1895) wrote, “The introduction of the word **Rostrum** for the cephalic pole of the axis of the body I deem an essential enrichment of our language. The adjective **Rostral** seems to me indispensable as an ontogenic expression.” (p. 110; see translation by Eycleshymer, 1917, p. 109). Also see *rostrocaudal axis*.

Rostrocaudal axis: Equally acceptable synonym for *longitudinal axis* (Barclay, 1803), but also indicating polarity or direction toward the oral (Schulze, 1893) or *rostral* (Schulze, 1893) end, or toward the aboral (Schulze, 1893) or *caudal* (Cleland, 1879) end, of the axis; see oral-aboral axis (Schulze, 1893); used recently by for example Kuhlenbeck (1973, p. 111), Nauta & Feirtag (1986, pp. 39-40) and Swanson (2003, pp. 223-228).

Rostrocaudal plane: Synonym for *longitudinal plane* (Henle, 1855).

Route: The physical course taken by a *connection* through *gray matter regions* and/or *white matter tracts*.

Sagittal plane (Henle, 1855): In animals with *bilateral symmetry*, the plane of section parallel to the *longitudinal axis* (Barclay, 1803) of the *body* and passing *dorsal* (Barclay, 1803)-*ventral* (Schulze, 1893), orthogonal to the other *longitudinal plane* (Henle, 1855), the *frontal plane* (Henle, 1855). Term introduced by Henle (1855, p. 2), also see Kuhlenbeck (1973, p. 114).

Schematic diagram: An illustration of the arrangement of *connections* that is more abstract than a *wiring diagram* because it is concerned more with topological than with physical relationships; see Wikipedia (Schematic diagram).

Secondary forebrain (Sharpey et al., 1867): Synonym for forebrain (Baer, 1837); p. 577.

Secondary hindbrain (Sharpey et al., 1867): Synonym for *hindbrain* (Baer, 1837); p. 577. Also used by for example Strong & Elwyn (1943, p. 13).

Site: An arbitrarily defined point, area, or volume in the *nervous system* (Monro, 1783) that may or may not correspond to a standard structural feature (term); examples include injection *site*, labeling *site*, lesion *site*, stimulation *site*, activation *site*, and sampling *site*. A *site* encompasses a *neuron population* (Burns, 2001).

Soma: Synonym for *cell body* (Deiters, 1865); see Peters et al. (1991, p. 14).

Somata: Pleural of *soma*.

Somatic spine: The equivalent of a *dendritic spine* on a neuron *cell body* (Deiters, 1865), the soma; see Swanson (1976a, p. 54).

Spinal bulb: Synonym for *medulla Winslow, 1733*); introduced for macrodissected adult humans by Chaussier (1807, p. 120).

Spinal cord (SP; Galen, c162-c166): The *caudal* (Cleland, 1879) *topographic division* of the *cerebrospinal axis* (Meckel, 1817); the *rostral* (Schulze, 1893) *topographic division* is the *vertebrate brain* (Cuvier, 1800). The usual criterion for distinguishing the two divisions in the adult is that the *vertebrate brain* lies within the skull whereas the *spinal cord* lies within the spinal (vertebral) column, although this is a difficult problem in practice; see Crosby et al. (1962, pp. 112-120). Definite knowledge of the *spinal cord* dates to Hippocrates in *Fleshes* (see translation by Potter, 1995, p. 139), and Galen (c162-c166) used the term specifically—see translation by De Lacy (1978, p. 85). Common synonyms include *medulla spinalis* (Hippocrates), or *spinal medulla* in English, and *spinal marrow* (Bannister, 1578).

Spinal marrow (Vesalius, 1543): Term included the *spinal cord* (Galen, c162-c166), *medulla* (Winslow, 1733), and *pons* (Haller, 1747) of macrodissected adult humans; see translation by Richardson & Carman (2002, p. 222).

Spinal marrow (Varolio, 1573): Term included the *spinal cord* (Galen, c162-c166), *medulla* (Winslow, 1733), *pons* (Haller, 1747), and *midbrain* (Baer, 1837) for macrodissected adult humans; Fig. 2(1-3) on f. 19r.

Spinal marrow (Bannister, 1578): English form of *medulla spinalis* (Hippocrates); see Bannister (1578, f. 106v).

Spinal medulla: English form of *medulla spinalis* (Hippocrates); see translations by May (1968, p. 575), Adams (1972, pp. 234, 309), and Potter (1995, p. 139).

Spinal nerve ganglia (GS; Burdach, 1819): The *topographic division* consisting of sensory *ganglia* (Galen, c173) associated with the *dorsal roots* of the *spinal nerve roots* (Tiedemann, 1816), divided into *cervical spinal ganglia*, *thoracic spinal ganglia*, *lumbar spinal ganglia*, and *coccygeal spinal ganglia*. They were discovered in macrodissected adult humans by Coiter (1572, see translation, 1995, pp. 113-115) and named thus by Burdach (1819, vol. 1, p. 136).

Spinal nerve plexuses (plx): A network of *communicating branches* (Winslow, 1733) between three or more *spinal nerves* (Camper, 1760); examples are the *cervical plexus* (Molinetti, 1675), *brachial plexus* (Camper, 1760), *lumbar plexus* (Vesalius, 1543), and *sacral plexus* (Vesalius, 1543). These *plexuses* (Galen, c192) were identified in macrodissected adult animals except humans in the second century by Galen; see translations of Duckworth (1962, pp. 230-264) and May (1968, pp. 598-603).

Spinal nerve primary branches (spb): In general, each *spinal nerve trunk* divides distally into a *spinal nerve dorsal branch* (Meckel, 1817) and a *spinal nerve ventral branch*; this arrangement was identified in macrodissected adult animals except humans in the second century by Galen; see translations by Duckworth (1962, p. 229 ff.) and May (1968, pp. 597-599); for contemporary terminology see Durward (1951, p. 1052 and Fig. 913).

Spinal nerve roots (srt; Tiedemann, 1816): In general, each of the *spinal nerves* (Camper, 1760) has a peripheral *dorsal root* and *ventral root* between the surface of the *spinal cord* (Galen, c162-c166) and the plane where they merge into a composite *spinal nerve trunk*. The *spinal nerve roots* were discovered in macrodissected adult

humans by Coiter (1572, see translation of 1995, p. 115); they were named such by Tiedemann (1816, see translation of 1826, p. 126).

Spinal nerve trunk (spt): The short segment of a *spinal nerve* (Camper, 1760) between the junction of the *dorsal root* and *ventral root*, and the origin of the *spinal nerve primary branches*; this arrangement was specifically described for macrodissected adult humans by Winslow (1733, Sect. VI, p. 76); for contemporary terminology see Durward (1951, Fig. 913).

Spinal nerves (spin; Camper, 1760): The *topographic division* of vertebrate *craniospinal nerves* (Herrick, 1915)—the other being *cranial nerves* (Longet, 1742)—that arises from the *spinal cord* (Galen, c162-c166) and exits the vertebral or spinal column, and is also distinguished from *autonomic nerves* (Langley, 1898). They are divided into groups of *cervical nerves* (Galen, c173), *thoracic nerves* (Diemerbroeck, 1672), *lumbar nerves* (Diemerbroeck, 1672), *sacral nerves* (Camper, 1760), and *coccygeal nerves* (Camper, 1762), as enumerated now for macrodissected adult humans. Most of them were known to Herophilus (335-280 BC), the founder of human anatomy (see Solmsen, 1961; von Staden, 1989), and the term itself was first used in the currently accepted way for macrodissected adult humans by Camper (1760). The synonym vertebral nerves (Willis, 1664) might be a more accurate match for *cranial nerves* (Longet, 1742).

Spine (Cajal, 1888): Short form of *dendritic spine* (Cajal, 1899), or *somatic spine*; p. 4, *espinas* in Spanish. It may of course also refer to the spinal (vertebral) column.

Standard term: A defined term that is chosen from a list of *synonyms* to represent a concept in the *Foundational Model of Connectivity*; reference term is a nonpreferred synonym.

Structural connection: A long form of *connection*.

Subarachnoid space (Magendie, 1827): The part of the *ventricular-subarachnoid space* that lies between the outer and inner layers of *meninges* (Edwin Smith Surgical Papyrus, c1700 BC), the *dura* (Galen, c177) and *pia* (Galen, c192), respectively; it is continuous with the *ventricles* (Hippocrates) and is filled with cerebrospinal fluid. The existence of fluid under the *dura*, in what is now called the *subarachnoid space*, was known to Hippocrates (see Millen & Woollam, 1962, p. 1), and named by Magendie (1827, pp. 21, 25) in a variety of macrodissected mammals.

Subsystems arrangement of gray matter regions: An essentially *neural network* arrangement of *gray matter regions* based on functional subsystems. Swanson (2004, Table B) provided a systematic example for a 4-subsystem network model of rat *central nervous system* (Meckel, 1817) organization.

Subsystems microarchitecture of nervous system: One of two common orthogonal ways to describe completely the *nervous system* (Monro, 1783). Subsystems here deal with the accurate microscopic (histological) delineation and description of *gray matter regions* and *white matter tracts*, in contrast to the *topographic description of nervous system* that deals with macroscopic locations in the *nervous system*. For the *nervous system* (Monro, 1783), *connections* and the *routes* they take are described in terms of *gray matter regions* and *white matter tracts*, which are formed by *neuron types* (Bota & Swanson, 2007), *neuron parts*, and *molecules*. An individual *nervous system* subsystem is a set of *connections* that form a complex unity with a specific function; also see *systems description of body*.

Superficial (Galen, c173): A relationship between adjacent objects in the *body*; an object is superficial to another when it is closer to the surface; the opposite of *deep*. The dichotomy has been used at least since the second century by Galen; see translation by May (1968, p. 715), also see Standring (2008, p. xxii).

Superior (Vicq d'Azyr, 1786): He defined it as above or toward the head in human anatomy; pp. 51, 116; also see Standring (2008, p. xxii) and anterior (Aristotle).

Supporting structures of nervous system: *Topographic macrostructure* features that include the connective tissue coverings of the *nervous system* (Monro, 17893)—the *meninges* (Edwin Smith Surgical Papyrus, c1700 BC)—and the compartment within and surrounding the *nervous system* that is filled with cerebrospinal fluid (CSF; in *ventricles-subarachnoid space*); see Millen & Woollam (1962). It is important to consider that the *circulatory system* pervades the *nervous system*.

Supraesophageal ganglion: *Invertebrate brain* that lies *dorsal* (Barclay, 1803) to the *digestive system* in annelids and arthropods. One or more *supraesophageal ganglia* may be involved, depending on how many *central nerve cords* there are in a species; see Bullock & Horridge (1965, pp. 662, 1609), Reisinger (1972), and *ventral ganglia*.

Synapse (Foster & Sherrington, 1897): Generally, a natural junction achieving functional conduction between distinct *neurons* (Waldeyer, 1891), or a *neuron* and another *cell* (Hooke, 1665), and accomplished through contact or near contact without regard to mechanism; see Bullock & Horridge (1965, pp. 181, 196). They are usually divided into *chemical synapses*, *electrical synapses*, and *mixed synapses*. The most common in adult vertebrates, the *chemical synapse*, is a structure-function differentiation consisting of three parts: a neuronal *presynaptic compartment* (De Camilli et al., 2001) where neurotransmitter is released from the *terminal* (Cajal, 1899), a *synaptic cleft* of variable width, and a *postsynaptic compartment* (De Camilli et al., 2001) that may or may not be neuronal but does have plasma membrane receptors for neurotransmitters. At classical unidirectional *chemical synapses* neurotransmitters may have feedforward effects on the *postsynaptic* membranes and feedback effects on *presynaptic* membranes. It is thought, however, that these *synapses* are rectifiers, with *neural network* information flowing from presynaptic *neuron* to postsynaptic *cell*, modulated by *presynaptic* neurotransmitter feedback. In contrast, reciprocal or bidirectional *chemical synapses* release neurotransmitter on both sides of the *synaptic cleft* and can thus transmit *neural network* information in either direction depending on network activity. Bidirectional *chemical synapses* are characteristic of *amacrine extensions* rather than *axons* (Kölliker, 1896). Finally, the distance between *presynaptic* membrane and *postsynaptic* membrane can vary enormously, from about 20-30 nm at classical *chemical synapses* like the neuromuscular junction, to microns for the sympathetic innervation of blood vessels, to centimeters or meters for neurotransmitter released into the blood. Foster & Sherrington (1897, pp. 929, 969) supplied the term; Cajal (1894b, p. 447) had earlier called it an articulation. See Bullock & Horridge (1965, Tab. 2.1), Peters et al. (1991, Ch. 5), Cowan et al. (2001), Standring (2008, p. 44-48).

Synapse en passant: French form of *synapse-of-passage*

Synapse in passing: Form of *synapse-of-passage*.

- Synapse-of-passage:** A *synapse* (Foster & Sherrington, 1897) formed by either a *terminal-of-passage* or a *bouton-of-passage*; see Gerfen & Sawchenko (1984, pp. 231, 235, Fig. 10-F), Peters et al. (1991, pp. 150, 187, 358).
- Synaptic bouton:** Synonym for *terminal* (Cajal, 1899); see Jones & Cowan (1983, p. 306).
- Synaptic cleft:** The extracellular fluid domain between the plasma membrane of a particular *presynaptic compartment* (De Camilli et al., 2001) and the plasma membrane of a *postsynaptic compartment* (De Camilli et al., 2001); see De Camilli et al. (2001, p 115).
- Synonym:** The semantic relationship between a *standard term* and a *synonym* is an identical definition, and for relevant *Foundational Model of Connectivity* terms implies identical *connections*.
- Systems description of body:** One of two common orthogonal ways of describing completely the *body*; the other is the *topographic description of body*. An individual *body system* is a set of interconnected or interdependent parts that form a complex unity with a specific function; see Dorland's (2003), Oxford English Dictionary (1989). A set of *body systems* together describes completely the structure-function organization of the *body*; see Brash (1951, p. 4), Hollinshead (1974, pp. v-vii), Williams (1995, pp. 2, 15). Also called a systematic description of body.
- Tectum (TC; Schwalbe, 1881):** The *dorsal* (Barclay, 1803) *topographic division* of the *midbrain* (Baer, 1837), essentially *dorsal* to the *cerebral aqueduct* (His, 1895) and dominated in mammals by the *superior colliculi* and *inferior colliculi*, and contrasting with the *ventral* (Schulze, 1893) *topographic division*, the *tegmentum* (Swanson, 2000). Galen (c177) pointed out the colliculi for macrodissected animals not including humans, referring to them as “little buttocks”; see translation by May (1968, p. 420). Schwalbe (1881, p. 454) apparently introduced the term as currently used, *Decke des Mittelhirns* in the original German; also see Cajal (1899-1904, vol 2, pt 1, p. 449), *el techo* and *la porción tectal* in the original Spanish. Also see Williams & Warwick (1980, p. 940), International Anatomical Nomenclature Committee (1983, p. A68), Federative Committee on Anatomical Terminology (1998, A14.1.06.601). Common synonym is *corpora quadrigemina* (Winslow, 1733).
- Tegmentum (Meckel, 1817):** The *tegmentum* (Swanson, 2000) without the *cerebral peduncle* (Tarin, 1753) *white matter tract*; see English translation (1832, vol. 2, p. 467), *Haube* in the original German. The Latin “tegmentum” (see Burdach, 1822, p. 101, who used the same definition) means “cap” or “covering” in English, and Meckel described it as such for the *cerebral peduncle* (Tarin, 1753). Hence the synonym for *cerebral peduncle* (Tarin, 1753), *basis pedunculi* (Meckel 1817; see English translation, 1832, vol. 2, p. 467); also see Ranson (1920, p. 158). Unfortunately, *basis pedunculi* later acquired a second meaning, the *cerebral peduncle* (Tarin, 1753) together with the *substantia nigra* (Soemmerring, 1791); see Henle (1871, p. 244), Strong & Elwyn (1943, p. 228), Crosby et al. (1962, pp. 221, 260).
- Tegmentum (Schwalbe 1881):** The *tegmentum* (Swanson, 2000) without the *cerebral peduncle* (Tarin, 1753) and *substantia nigra* (Soemmerring, 1791); p. 450 ff. Later used thus by for example Obersteiner & Hill (1900, p. 69), Crosby et al. (1962, pp. 221, 260, 262), Carpenter (1976, p. 384), Williams & Warwick (1980, p. 935 ff.).

- Tegmentum (Kölliker, 1896): Defined as a synonym for the *substantia reticularis grisea* [reticular gray matter] of the *midbrain* (Baer, 1837), *pons* (Haller, 1747), and *medulla* (Winslow, 1733); pp. 209-223. Also see Anthoney (1994, pp. 528-532).
- Tegmentum (Carpenter, 1976): The tegmentum (Schwalbe, 1881) combined with a corresponding part of the caudally adjacent *pons* (Haller, 1747) between the *pontine gray* (Reil, 1809) and *cerebellum* (Aristotle); pp. 322, 384. The term may predate Carpenter.
- Tegmentum (TG; Swanson, 2000):** The *ventral* (Schulze, 1893) *topographic division* of the *midbrain* (Baer, 1837); the *dorsal* (Barclay, 1803) *topographic division* is the *tectum* (Schwalbe, 1881). Meckel (1817; see English translation, 1832, vol. 2, p. 467) apparently introduced the term and roughly its definition here for macrodissected adult humans, except he excluded the *cerebral peduncle* (Tarin, 1753), a *white matter tract* at the base of the *midbrain*, which is still common today but is included here. As defined here, *tegmentum* refers to the whole of the *midbrain* (Baer, 1837) excluding the *tectum* (Schwalbe, 1881) but including the *pretectal region* (Scalia, 1972); see Swanson (2000, pp. 522, 526). Usage of this term is very complex, inconsistent, and illogical; see for example Crosby et al. (1962, pp. 221, 260, 262), Carpenter (1976, p. 367 ff.).
- Telencephalic nuclei (Crosby et al., 1962): Synonym for basal ganglia of telencephalon (Ranson, 1920) in macrodissected adult humans, and is thus not synonymous with *cerebral nuclei* (Swanson, 2000); p. 356.
- Telencephalon (His, 1893b): Based on comparative embryology including human, it included the *endbrain* (Kuhlenbeck, 1927) and the preoptic, anterior, and tuberal regions (see Swanson 1987, p. 2) of the *hypothalamus* (Kuhlenbeck, 1927); pp. 173, 178, 179; also see His (1895, p. 158).
- Telencephalon (Kuhlenbeck, 1927): Original Latin form of vertebrate *endbrain* (Kuhlenbeck, 1927); chs. 3, 10.
- Telencephalon impar (Kuhlenbeck (1929): Synonym for telencephalon medium (Herrick, 1910); p. 24, also see Crosby et al. (1962, p. 343).
- Telencephalon medium (Herrick, 1910): The *unevaginated* part of the telencephalon (His, 1893b) surrounding the *rostral* (Schulze, 1893) end of the *third ventricle* (Galen, c173), and basically comprising the preoptic region (Swanson, 1976b) of the *hypothalamus* (Kuhlenbeck, 1927); see Strong & Elwyn (1943, p. 19), Crosby et al. (1962, p. 343). In English, the median telencephalon; see Strong & Elwyn (1943, p. 274)—as contrasted with the *evaginated cerebral hemispheres* (Tiedemann, 1826). It was clearly defined by Herrick (1910, pp. 493-495) and presaged by Johnston (1909, p. 513).
- Telodendria (Rauber, 1897): Originally the end branches of an *axon* (Kölliker, 1896)—the *terminal arborization* (Cajal, 1888)—or of a *dendrite* (His, 1889), with each individual branch a *teledendron* (singular); Rauber (1897, p. 74), see Barker (1899, p. 82), Böhm et al. (1926, p. 150). Now it usually refers just to the end branches of an *axon*; see Jones & Cowan (1983, p. 306, note).
- Term: See *standard term*, reference term, *synonym*, *partial correspondence*.
- Terminal (Cajal, 1899):** A general term that refers to an *axon terminal* (Barker, 1899) and/or *synapse-of-passage*; its characteristic feature is a slight rounded swelling that is *presynaptic*; Cajal used for Golgi material, p. 67.

Terminal arborization (Cajal, 1888): Abundant branching at the end of an *axon trunk* or *axon collateral* (Cajal, 1899), typically with abundant *axon terminals* (Barker, 1899) and *axon varicosities*; used by Cajal (1888, p. 10) for Golgi material of bird *cerebellum* (Aristotle); also see Strong & Elwyn (1925, p. 173). Synonym is telodendria in its modern sense.

Terminal autonomic nerves (TAN): A *topographic division* of *autonomic nerves* (Langley, 1898) that macroscopically appear to arise mostly from *terminal ganglia* (Gaskell, 1886) and/or *terminal plexuses*; nicely illustrated for macrodissected adult humans by Ranson (1920, Fig. 250).

Terminal bouton (Auerbach, 1898): Synonym for *axon terminal* (Barker, 1899); named by Auerbach (1898); see Peters et al. (1991, pp. 150, 187, 358).

Terminal en passant: Synonym for *terminal-of-passage*.

Terminal ganglia (GT; Gaskell, 1886): A *topographic division* of *autonomic ganglia* (Langley, 1900) lying on or in the walls of innervated viscera; named thus by Gaskell (1886, p. 3) for vertebrates based on structure-function criteria.

Terminal-of-passage: A *terminal* (Cajal, 1899) on a very short stalk that protrudes from an *axon trunk* or *axon collateral* (Cajal, 1899) along its course rather than at the *terminal arborization* (Cajal, 1888) of the trunk or collateral. With the light microscope they resemble *dendritic spines*. See Fox & Barnard (1957, Fig. 9), Gerfen & Sawchenko (1984, pp. 231, 235, Fig. 10-F).

Terminal plexuses (TPL): A *topographic division* of *autonomic nerves* (Langley, 1898) that form more or less discrete anastomoses of small *white matter tracts* (bundles) in or near the walls of innervated viscera. They are characterized by parasympathetic ganglion cells that only sometimes condense into macroscopically obvious *terminal ganglia* (Gaskell, 1886). The distinction between *terminal plexuses* and *prevertebral plexuses* is clearly illustrated by Ranson (1920, Fig. 250) and Williams & Warwick (1980, Fig. 7-224, and pp. 1122-1137).

Termination: The *neuron* (Waldeyer, 1891), *neuron type* (Bota & Swanson, 2007), or *gray matter region* where a *connection* or *output* ends; see Herrick (1915, p. 108).

Thalamus (Galen, c173): In at least one instance this term clearly referred to the inferior horn of the *lateral ventricle* (Vesalius, 1543); see translation by May (1968, p. 687).

Thalamus (Malpighi, 1673): Basically a synonym for *interbrain* (Baer, 1837), used in his description of chick development, and short for “thalami nervorum opticorum”; see translation of Adelman (1966, p. 967).

Thalamus (TH; His, 1893a): The *dorsal* (Barclay, 1803) *topographic division* of the *interbrain* (Baer, 1837); the *ventral* (Schulze, 1893) *topographic division* is the *hypothalamus* (Kuhlenbeck, 1927). The macrodissected adult human *thalamus* was clearly illustrated by Vesalius (1543; see translation by Singer, 1952, Figs. 4-8) and the term as defined here was introduced by His (1893a, pp. 161-162). It includes the traditional epithalamus, dorsal thalamus, and ventral thalamus of Herrick (1910, pp. 494, 498); also see Kuhlenbeck (1927, Ch. 9) and Jones (1985, p. 87).

Third ventricle (V3; Galen, c173): The part of the *ventricles* (Hippocrates) in the *median plane* (Henle, 1855) of the *interbrain* (Baer, 1837), continuous *rostrally* (Schulze, 1893) with the *lateral ventricles* (Vesalius, 1543) and *caudally* (Cleland, 1879) with the *cerebral aqueduct* (His, 1895). Galen (c173; see translations by May,

1968, p. 141 and Singer, 1999, p. 234) discovered and named the *third ventricle* in the macrodissected adult ox.

Topographic arrangement of gray matter regions: A hierarchical arrangement of *gray matter regions* based strictly on a particular scheme of *topographic divisions*, including *topographic divisions of cerebrospinal axis*. Swanson (1992, Table A) provided a systematic example for the 10 elementary *topographic divisions of cerebrospinal axis* of the adult rat.

Topographic description of body: One of two common orthogonal ways of describing completely the *body*; the other is the *systems description of body*. Topography here deals with the accurate geometric delineation and description of locations in the *body*; see Oxford English Dictionary (1989). For mammals the major locations are head, neck, trunk, and extremities. A hierarchical set of topographic locations together describes completely the *body* from a structural perspective; see Brash (1951, p. 3), Hollinshead (1974, pp. v-vii), Williams (1995, pp. 2, 15).

Topographic division: A macrostructural part of the *nervous system* (Monro, 1783) created at least conceptually by cutting (dividing) with a knife between defined structural landmarks and fitting into a recognized macrostructural hierarchy; see Swanson (2000). The *central nervous system* (Meckel, 1817) and *peripheral nervous system* (Meckel, 1817) are the two major topographic divisions, except in animals with just a *nerve net*, which has divisionless topography.

Topographic divisions of cerebrospinal axis: Since Classical Antiquity at least six fundamentally different ways to divide the *cerebrospinal axis* (Meckel, 1817) have been used, although today there is rather broad consensus about a set of major *topographic divisions*. The set of divisions is arranged in a hierarchical parceling scheme that is based primarily on structural differentiation of the *neural tube* (Baer, 1837) and its end product in adult macrostructure or gross anatomy (Swanson, 2000). There are 10 *elementary divisions* at the bottom: *cerebral cortex* (Bauhin, 1605), *cerebral nuclei* (Swanson, 2000), *thalamus* (His, 1893a), *hypothalamus* (Kuhlenbeck, 1927), *tectum* (Schwalbe, 1891), *tegmentum* (Swanson, 2000), *cerebellum* (Aristotle), *pons* (Haller, 1747), *medulla* (Winslow, 1733), and *spinal cord* (Galen, c162-c166). There is considerably more controversy about smaller *topographic divisions* below the level of the ten elementary divisions. The 17 terms in the hierarchy below *cerebrospinal axis* (Meckel, 1817) are very useful “building blocks” that may be combined in many ways to create new terms, like *brainstem*, which can have different meanings depending on which elementary divisions are included (Swanson, 2000, Tab. 1).

Topographic macroarchitecture of nervous system: One of two common orthogonal ways to describe completely the *nervous system* (Monro, 1783). Topography here deals with the accurate macroscopic (gross anatomical) delineation and description of major locations in the *nervous system*, in contrast to the *subsystems description of nervous system* that deals with the microscopic-histological organization of *gray matter regions* and *white matter tracts*—and the *connections* they form. A topographic location in the *nervous system*, like the *midbrain* (Baer, 1837), is usually a heterogeneous mixture of components, including parts of the *circulatory system*, *meninges* (Edwin Smith Surgical Papyrus, c1700 BC), *ventricles-subarachnoid space*, *gray matter regions*, and *white matter tracts*.

Tract: Shortened form of *white matter tract*.

Transverse axis (Henle, 1855): The axis orthogonal to the *longitudinal axis* (Barclay, 1803) or *rostrocaudal axis* of the *body* in all animals with a *nervous system* (Monro, 1783); term introduced by Henle (1855, p. 1). In animals with *radial symmetry* it is the only axis orthogonal to the *longitudinal axis* (Barclay, 1803); in animals with *bilateral symmetry* it is divided into a *dorsoventral axis* and an orthogonal *mediolateral axis* with right and left halves; see Kuhlenbeck (1973, p. 112).

Transverse plane (Henle, 1855): The plane of section orthogonal to the *longitudinal axis* (Barclay, 1803), dividing the body into *rostral* (Schulze, 1893) and *caudal* (Cleland, 1879) parts. Term introduced by Henle (1855, p. 1), also see Kuhlenbeck (1973, p. 114).

Transverse tract: A *white matter tract* coursing essentially along the *transverse axis* (Henle, 1855) of the *nervous system* (Monro, 1783); if a *transverse tract* crosses the *median plane* (Henle, 1855) in an animal with *bilateral symmetry*, the segment related to that plane is a *commissure*. The basically transverse and longitudinal organization of nervous system tracts was emphasized early on by Spencer (1881) and Cajal (1899-1904, vol. 1, p. 12), and more recently in the orthogon theory of Reisinger (1925, 1972).

Unmyelinated axon: An *axon* (Kölliker, 1896) with no *myelin sheath*. Axons below a threshold diameter characteristic of particular species remain unmyelinated, thus forming the set of thinnest *axons*; see Williams (1995, pp. 951-954). The (unmyelinated) *axon* was discovered by Remak (1837) who called it a primitive band.

Vascular cells: They form the blood vessels and blood cells within them and are part of the *circulatory system*; see Peters et al. (1991, Ch. 10).

Ventral (Schulze, 1893): Toward the belly of the *body*, or away from the back, in the *transverse plane* (Henle, 1855); the opposite of *dorsal* (Barclay, 1803). See Schulze (1893, p. 5), and Brusca & Brusca (1990, p. 46).

Ventral ganglia: The invertebrate *central ganglia* lying *caudal* (Cleland, 1879) to the *supraesophageal ganglion* and *ventral* (Schulze, 1893) to the *digestive system* on a *central nerve cord trunk*; the *central ganglia* and *central nerve cord trunk* together form a *central nerve cord*. See Bullock & Horridge (1965, p. 662).

Ventricles (CEV; Hippocrates): The part of the *ventricular-subarachnoid space* that lies within the vertebrate *central nervous system* (Meckel, 1817); they are continuous with the *subarachnoid space* (Magendie (1827) and are filled with cerebrospinal fluid (CSF). The (cerebral) *ventricles* were probably known to Anaxagoras of Athens (c488-428 BC; see Mettler, 1947, p. 10; Rasmussen, 1947, p. 1) and were named by Hippocrates in *On the Sacred Disease* (see translation by Adams, 1972, p. 353).

Ventricular-subarachnoid space (VSS): The continuous cavity associated with the vertebrate *central nervous system* (Meckel, 1817) that is filled with cerebrospinal fluid (CSF). Part of the cavity is the central lumen of the vertebrate *central nervous system* (Meckel, 1817) that is the remnant of the embryonic lumen of the *neural tube* (Baer, 1837); it is referred to as the (cerebral) *ventricles* (Hippocrates), with walls formed by a monolayer of ependymal cells, a type of *glia* (Virchow, 1846). The other part is the *subarachnoid space* (Magendie, 1827) that lies between the outer and inner layers of *meninges* (Edwin Smith Surgical Papyrus, c1700 BC), the *dura*

(Galen, c177) and *pia* (Galen, c192), respectively. The *ventricles* and *subarachnoid space* are continuous through holes in the roof of the *fourth ventricle* (Galen, c177) associated with the *medulla* (Winslow, 1733). The CSF is equivalent to lymph for the *central nervous system* and eventually drains into the venous part of the *circulatory system*; see Crosby et al. (1962, pp. 568-579).

Ventricular system (VS): Synonym for *ventricles* (Hippocrates).

Vertebrate brain (BRv; Cuvier, 1800): The *rostral* (Schulze, 1893) *topographic division* of the *cerebrospinal axis* (Meckel, 1817; the *caudal* (Cleland, 1879) division is the *spinal cord* (Galen, c162-c166). The usual criterion for distinguishing the two divisions in the adult is that the *vertebrate brain* lies within the skull whereas the *spinal cord* lies within the spinal (vertebral) column, although this is a difficult problem; see Crosby et al. (1962, pp. 112-120). An ancient Egyptian hieroglyph that refers to the human *brain* (Edwin Smith Surgical Papyrus, c1700 BC) probably dates back some five thousand years; see Longrigg (1998, p. 84), Nunn (2002, pp. 43, 50-51, 217), and Rocca (2003, p. 21). The brain of vertebrate animals was described by Cuvier (1800, vol. 2, p. 93).

Vertebrate central nervous system: See *cerebrospinal axis* (Meckel, 1817).

Vertebrate central nervous system divisions: See *topographic divisions of cerebrospinal axis*.

White matter (WM; Meckel, 1817): Since the 16th century the *nervous system* (Monro, 1783) has been divided more and more precisely into *gray matter* (Meckel, 1817) and *white matter* based on their appearance in freshly dissected material observed with the naked eye (macroarchitecture); since the 19th century this differentiation has been made at the histological (microarchitecture) level. *White matter* is the *nervous system* compartment that consists primarily of *axons* (Kölliker, 1896). Its name is derived from its appearance in fresh and fixed macroscopically observed material, its whitish color due to the presence of *myelinated axons*. However, *white matter* is often a mixture of *myelinated axons* and *unmyelinated axons*, and entire aggregates of *axons* can be unmyelinated. Therefore, as defined here *white matter* is a generic term for a *nervous system* volume where *axons* are the predominant neural component, although of course *glia* (Virchow, 1846) and parts of the *circulatory system*, *vascular cells*, are also present. *White matter* can contain scattered *neurons* (Waldeyer, 1891) that may be assigned either to an adjacent *gray matter region*, or to a new *gray matter region* embedded (nested) within the *white matter*; assignment depends on differentiable *neuron types* (Bota & Swanson, 2007) involved. There is often a fuzzy border of variable width and difficult to measure between *gray matter* and *white matter*. This use of the term was probably introduced by Meckel; see English translation (1832, vol. 2, pp. 152-154), also see Herrick (1915, p. 108). For early history see Clarke & O'Malley (1996, Ch. 10); for modern histological interpretation see Peters et al. (1991), Swanson (2003, pp. 60-66).

White matter tract: A recognizable division of *white matter* (Meckel, 1817) in the *nervous system* (Monro, 1783) that can be bordered by *gray matter* (Meckel, 1817), another *white matter tract(s)*, or non-neural tissue. Borders between *white matter tracts* are determined by defined structural landmarks and are commonly arbitrary. *White matter tracts* may be homogenous or heterogeneous. A *homogeneous tract* only has one specific *mesoconnection* (Thompson & Swanson, 2010) within it,

whereas a *heterogeneous tract* has two or more specific *mesoconnections* within it. The traditional way to view vertebrate *white matter tracts* is with a myelin stain, supplemented with a reduced silver stain (Brodal, 1981, p. 5). There are many general terms for a *white matter tract*; some examples include pathway, bundle, fascicle, funiculus, column, peduncle, decussation, commissure, and nerve, whereas others have specific names like corpus callosum, fornix, and internal capsule. As a complete set, *white matter tracts* can be arranged in various ways, for example, strictly topographically into *transverse tracts*, *longitudinal tracts*, and *local tracts*. *White matter tracts* were distinguished in the second century by Galen (c177; see translation by Singer, 1999, pp. 231, 234) for macrodissected nonhuman mammals, and were referred to as tracts as long ago as Willis (1664; see translation by Pordage, 1681, pp. 61, 91) for macrodissected adult humans and other large mammals.

Wiring diagram: An illustration of the physical arrangement of *connections* (including *route* information) between a set of *nodes*—*gray matter regions*, *neuron types* (Bota & Swanson, 2007), or *neurons* (Waldeyer, 1891)—in the *nervous system* (Monro, 1783). *Wiring diagrams* can be at various levels of abstraction from three-dimensional models to two-dimensional schema but a complete *wiring diagram*, by definition, includes *route* information; see Gregory (1966), Wikipedia (Wiring diagram).

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Guidelines and requirements for term definitions are considered in the main text of Swanson & Bota (2010) and in [Supporting Text: Principles and Practices for FMC Modification](#). In the spirit of the guidelines and requirements for definitions at least the structural terms in the controlled vocabulary ideally (*i*) must provide the literature reference for the first identification (“discovery”) of the defined concept along with the term and method used and the species involved, (*ii*) must reference the first use of the current term as generally defined (along with method and species), and (*iii*) may provide contemporary authoritative reviews or analyses. At least one category of literature referencing is required initially, with the others supplied as determined. These requirements are formulated to acknowledge the fundamental importance of priority in science (International Commission on Zoological Nomenclature, 1999, p. 24), to distinguish easily between various synonyms and partly corresponding terms, and hopefully to slow the proliferation of gratuitous synonyms. Unreferenced terms are those presented here for the first time. Controlled vocabularies for describing experimental methods and results are beyond the scope of this article and will be dealt with elsewhere.

Definition format. Definitions for neuroanatomical standard terms (concepts) have this general form:

Standard term (abbreviation; reference for current name): Definition within FM framework with aid of other *standard terms* (*Reference*). Discovered by (reference). If discoverer and provider of current name are undetermined, cite “see reference(s)” for especially helpful information, and provide information when determined. Provision of no references at all implies that this publication is the reference term’s definition source; for later versions this publication becomes the current term’s source.

Abbreviation. The system for generating abbreviations has been described elsewhere (Swanson, 1992, p. 45) and most abbreviations are from (Alvarez-Bolado & Swanson, 1996; Swanson, 2004). The main features are that topographic divisions and gray matter regions are abbreviated with upper case letters, their subdivisions are indicated in lower case following the main abbreviation (e.g., MPNm refers to the medial part of the medial preoptic nucleus), and white matter tracts are indicated by lower case letters alone. In practice this is an immense job because unique abbreviations (preferably

not case sensitive for purposes of unambiguous text searching) are needed for structures at all stages of development and in the adult, not only for a particular species, but also for all animals with a nervous system.

Reference for current name. This is provided to the best of our current knowledge and is subject to future correction. If the origin is unknown, it was probably after 1840, and no date is used until proper documentation is obtained. For greatest clarity in text this format is recommended: *standard term (Jones, 1928)*, synonym (Smith, 1942). The surname in this format is not an eponym (Barker, 1907, p. 7), it is an attribution of priority.

Definition. Each textual definition must be framed within the overall FMC scheme, and thus be internally consistent with the definitions of all other terms.

Reference for discovery. Assignment of priority for discovery is fundamentally important and fair, but complex. It may involve description without naming or illustration, illustration without naming or description, illustration and description without naming, or naming with or without description and illustration. In general, reference terms toward the top of the concept hierarchy were discovered earlier because they are physically larger and conceptually broader. This trend is obvious in the thesaurus presented here.

Synonyms. The semantic relationship between standard term and synonym is identical definition, and for relevant FMC terms implies identical connections. Synonyms may have been created before or after the current name for a concept-standard term.

Partial correspondence. In a hierarchical arrangement of structural objects, terms can be standard, synonyms, or partial correspondences. Standard terms are defined concepts chosen to form the hierarchy objects, and synonyms are terms with definitions identical to particular standard terms. In a hierarchy, standard terms and their synonyms form a rigid series of *PART-OF* relationships. In neuroanatomy many terms only partly correspond to a standard term (or its synonyms) and thus do not fit exactly into any part of the hierarchy—each of them only *partly corresponds* to a standard term somewhere in the hierarchy, and should be defined with reference to that immediately higher standard term (Fig. S1). The concept of a party corresponding term is important because such a term does not share all of the properties of any reference concept and thus cannot fit anywhere within the hierarchy *per se*—it does not have a strict *PART-OF* relationship with the FMC hierarchy. This is a consequence of the fact that *gray matter regions* and *neuron types* in general are not homogeneous; instead, they have defining and differentiable features. As a result different *sites* within a gray matter region generally have different features and thus different connections.

Notes. In the thesaurus, concepts (preferred standard terms with a definition) are **bolded** at the start of an entry and *italicized* in the body of a definition. Use of nonpreferred terms (synonyms) is discouraged and use of terms outside the lists is not (in principle) allowed; the latter should be defined formally in an alternate scheme mapped to the FMC.

The thesaurus is arranged in a single alphabetical list. It is derived from five categories of terms, (i) General Terms for FMC; (ii), Symmetry and Positional Information: Terms for FMC; (iii) Schema: Terms for FMC; (iv) Cell Types, Neurons, and Neuron Parts: Terms for FMC; and (v) Connections with Routes: More Terms for FMC.

