

Staging of the Early Embryonic Brain in the Baboon (*Papio cynocephalus*) and Rhesus Monkey (*Macaca mulatta*)*

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Summary. Early morphogenesis of the brain and its derivatives was studied in sixty-nine baboon and rhesus monkey embryos representing developmental stages 8–16, and compared with the staged human embryo. The baboon and rhesus monkey embryos develop in a similar temporal sequence when compared with human embryos with the following exceptions: 1) The respective developmental events for otic disc, adeno-hypophyseal pouch, and hippocampal internal sulcus formation in the baboon and rhesus monkey occur at stage 10, stages 11–12, and after stage 16, while the comparable stages in humans are 9, 10, and 16; 2) Alternatively, formation of the trigeminal primordium and the motor root of the trigeminal nerve and evagination of the neurohypophysis occur earlier in the baboon and rhesus monkey (i.e., stages 12–13, stage 14, and stage 15, respectively) than observed in the human embryo (stage 14, stage 15, and stage 16, respectively); and 3) Lens pore closure in baboon and human embryos takes place during stage 14, while in the rhesus monkey closure occurs during stage 15.

Key words: Central nervous system – Embryology – Rhesus monkey – Baboon.

Introduction

Early morphogenesis of the brain in the primate embryo has been well described for the human (Streeter 1912; Hines 1922; Bartelmez and Evans 1926; Bartelmez and Dekaban 1962; O’Rahilly 1963, 1966; Gasser 1967; Humphrey 1968; Yokoh 1968; O’Rahilly and Gardner 1971; Gasser 1975), but only briefly (Van Campenhout 1948; Gilbert and Heuser 1954; Hendrickx and Sawyer 1975) or selectively

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so (Gasser and Hendrickx 1967, 1969; Hendrickx et al. 1971; Wilson et al. 1975, 1976; Wilson and Hendrickx 1977) for the nonhuman primate.

This study has been undertaken to provide a chronologically ordered (staged) description of the morphological development of the brain and related structures in early baboon and rhesus monkey embryos and to compare this development with that described by O'Rahilly and Gardner (1971) for the staged human embryo. This information will be of value in future embryological and teratological investigations involving the embryonic brain in these species.

Materials and Methods

Sixty-nine baboon (*Papio cynocephalus*) and rhesus monkey (*Macaca mulatta*) embryos ranging in age from 19 to 42 days of gestation were used in this study. The embryos belong to collections housed at the California Primate Research Center (CPRC) and the Carnegie Laboratories of Embryology (CLE), University of California, Davis. All embryos were studied microscopically and staged according to criteria previously established for the human (Streeter 1942, 1945, 1948, 1951; O'Rahilly 1973), the baboon (Hendrickx et al. 1971), and the rhesus monkey (Hendrickx and Sawyer 1975). From two to eleven embryos of each species were studied for each of the nine embryonic stages, 8 through 16.

Carefully supervised breeding programs were designed to produce embryos of known gestational age. Methods used by Hartman (CLE) and Hendrickx (CPRC) to accomplish this differed in several respects. Briefly, Hartman (1932) used rectal manual palpation of the ovaries in conjunction with menstrual cycle records to determine when ovulation would occur. A review of the breeding records indicates that at the time of or following ovulation female rhesus monkeys were bred for 4 to 6 h on one day or two consecutive days, or continuously (overnight) for a variable length of time. Hendrickx et al. (1971) used menstrual cycle records to determine when to breed females for 2 to 12 h on one specific day of the cycle. That day, the expected day of ovulation, corresponded to the third day prior to perineal deturgescence in the baboon and the second day before midcycle in the rhesus monkey (Hendrickx et al. 1971; Hendrickx and Sawyer 1975). The day of the single mating was designated as day 0 of pregnancy and was the basis for the estimated fertilization age.

The embryos were collected by hysterotomy using procedures described by Hartman (1944, CLE) and by Hendrickx et al. (1971, CPRC). The embryos were then fixed in Bouin's fluid, 10% buffered formalin, or Serra's fixative, embedded in paraffin (CPRC) or celloidin and paraffin (CLE), and sectioned serially at 5 to 10 microns in transverse or sagittal planes. Staining was done primarily with Masson's trichrome and hematoxylin and eosin (and phloxine, CLE) (Heuser and Streeter 1941; Heard 1957; Hendrickx et al. 1971; Hendrickx and Sawyer 1975). In addition, several baboon embryos were stained with Protargol stain, and ten rhesus monkey embryos were labeled in utero with ^3H -thymidine and processed by a method described by Sawyer et al. (1974). Photographs of each embryo taken prior to or following fixation were used to study external morphology. External measurements (greatest or crown-rump length) were made with calipers prior to or during fixation, or by counting sections of a known thickness after the embryo was mounted on microscopic slides. Internal measurements were made using American Optical or Zeiss ocular micrometers or by counting sections of known thickness. All photomicrographs were taken with a Zeiss photomicroscope. Graphic reconstructions prepared by methods described by Hendrickx et al. (1971) were studied when necessary to elucidate questions on internal morphology.

Results

The results are presented in the following format for each embryonic stage. External and internal characteristics are described in a cranial-caudal order.

Table 1. Baboon and rhesus monkey embryos used in brain development study

Stage	Estimated fertilization age (days)		Greatest or crown-rump length (mm) ^a		Number of embryos studied	
	Rhesus monkey	Baboon	Rhesus monkey	Baboon ^b	Rhesus monkey	Baboon
8	19–20	19–22	0.8–1.4	0.6–1.4	3	5
9	21–22	22–24	1.0–2.0	1.0–2.0	2	4
10	21–24	24–26	2.0–3.5	2.0–3.5	5	6
11	24–26	26–28	3.0–4.0	2.0–4.5	2	4
12	25–27	27–29	4.0–5.5	3.0–4.5	4	4
13	26–28	28–29	4.5–6.0	4.5–6.0	5	2
14	27–29	29–31	5.0–8.0	6.0–7.0	3	5
15	29–32	30–32	7.0–9.0	6.0–8.0	7	4
16	31–34	32–42	8.0–11.0	7.0–9.0	2	2

^a Greatest length for stages 8–12; crown-rump length for stages 13–16

^b From Hendrickx et al. (1971)

Structures mentioned in one stage are not discussed later if size increase is the only evidence of development. The estimated fertilization age, greatest or crown-rump length, and number of specimens studied for each stage are presented in Table 1.

Stage 8 (Presomite)

The neural plate ectoderm appears in the more advanced embryos as a shallow neural groove with neural folds (Fig. 1).

Stage 9 (1–3 Pairs of Somites)

External Characteristics. The cephalic (mesencephalic, cranial) flexure forms in the presumptive mesencephalic region. The neural folds enlarge, forming a deep neural groove (Fig. 2). The cranial end of the neural groove forms a distinct terminal notch. The caudal end of the neural groove is deeper than the cranial end.

Internal Characteristics. The prosencephalic, mesencephalic, and rhombencephalic regions of the neural folds can be identified by external or internal limiting sulci. A distinct isthmus separates the mesencephalon from the rhombencephalon. Neuromeres (rhombomeres) begin to appear in the rhombencephalic portion of the neural folds.

Stage 10 (4–12 Pairs of Somites)

External Characteristics. The closure of the neural folds to form the neural tube begins at the rhombencephalic-spinal cord junction (between somites 2

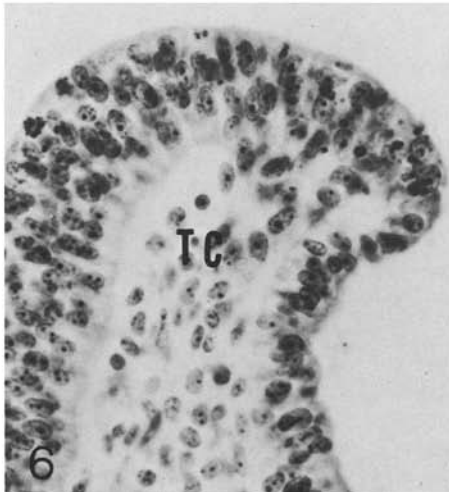
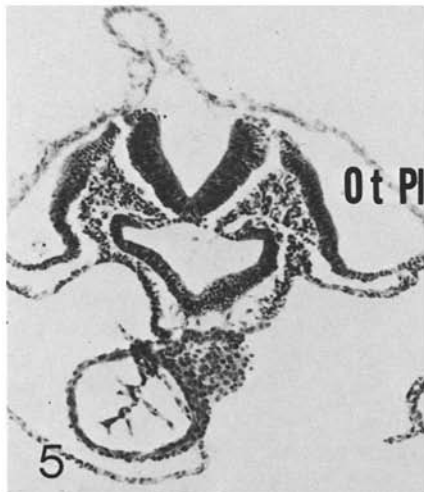
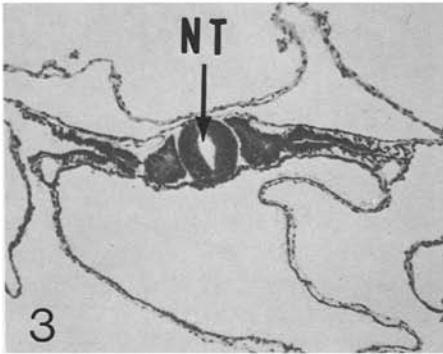
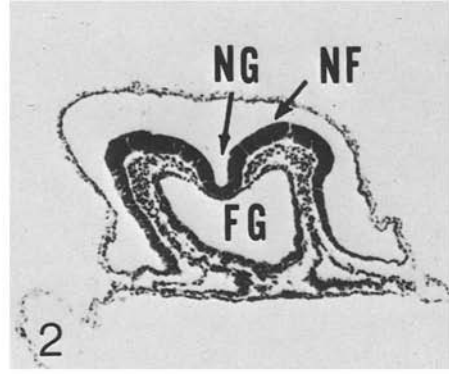
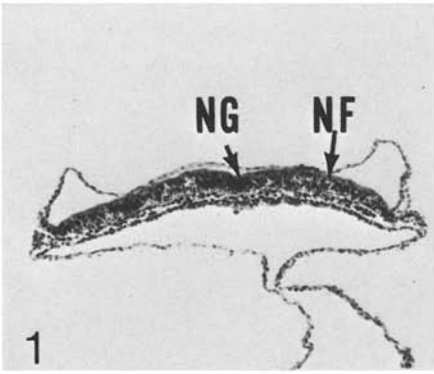


Fig. 1. Transverse section of a stage 8 baboon embryo showing neural folds (*NF*) and neural groove (*NG*). $\times 80$

Fig. 2. Transverse section of a stage 9 baboon embryo showing neural groove (*NG*), neural folds (*NF*) and foregut (*FG*). $\times 80$

Fig. 3. Transverse section of a stage 10 baboon embryo showing a closed neural tube (*NT*). $\times 80$

Fig. 4. Transverse section of a stage 10 baboon embryo showing the optic primordium (*arrow*) in the prosencephalic region of the neural fold. $\times 80$

Fig. 5. Transverse section of a stage 10 baboon embryo showing the otic plates (*OtPl*). $\times 100$

Fig. 6. Transverse section through trigeminal neural crest (*TC*) emerging from preotic rhombencephalic neural fold in an advanced stage 10 rhesus monkey embryo. $\times 432$

and 7 in the rhesus monkey and between somites 4 and 8 in the baboon) (Fig. 3). The optic primordia form cranial to the prominent cephalic flexure (Fig. 4), while the trigeminal and otic prominences are apparent caudal to the flexure. The otic plates appear as indistinct ectodermal thickenings on the dorso-lateral surface of the otic prominences (Fig. 5).

Internal Characteristics. The optic primordium can be recognized as dorsolateral thickenings of the prosencephalic region of the neural fold. In advanced embryos of this stage a prominent optic sulcus appears. The trigeminal neural crest emerges from the caudal mesencephalic and preotic regions of the neural folds (Fig. 6). The facioacoustic neural crest emerges from the otic region of the neural folds. The postotic neural crest appears during stage 10 or 11.

Stage 11 (13–20 Pairs of Somites)

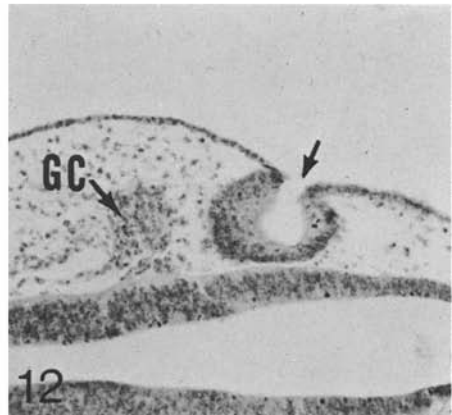
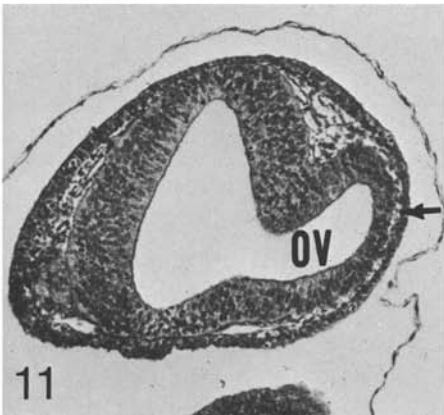
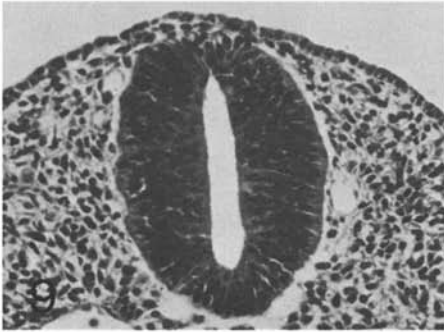
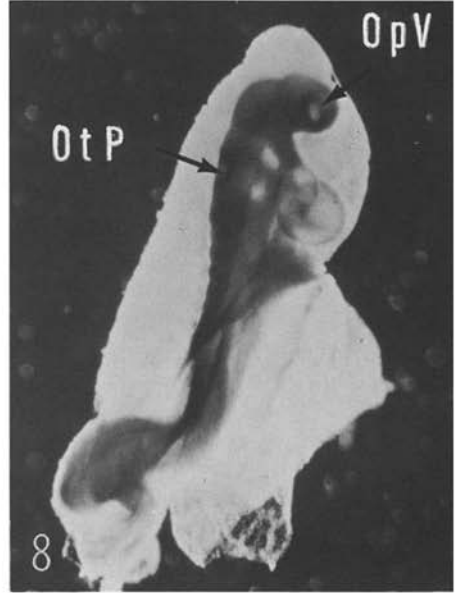
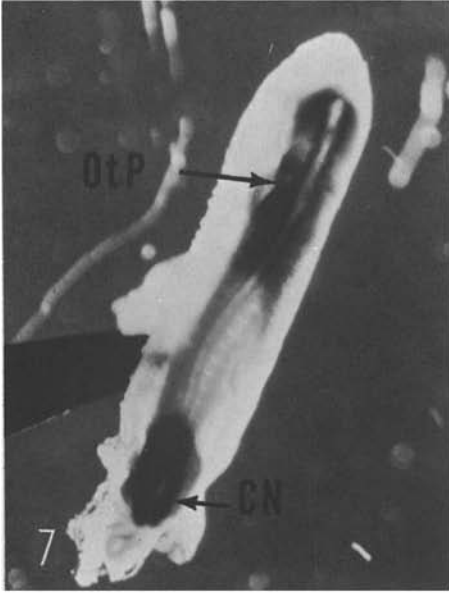
External Characteristics. The cranial (anterior) neuropore is closing or closed, and the caudal neuropore is apparent. The optic vesicle and the otic pit are distinct. The neural tube and folds extend the entire length of the embryo (Figs. 7 and 8). The embryo is characterized by a dorsal flexion of the body.

Internal Characteristics. The closing of the cranial neuropore forms the lamina terminalis. The telencephalon medium and the primordia of the corpus striatum and thalamus can be identified. The adenohipophyseal pouch begins to form in stage 11 or 12. The optic vesicle shows caudal and rostral limiting sulci and an optic cavity. The optic vesicle is in loose contact with the surface ectoderm. Neural crest cells emerge from the wall of the optic vesicle. The mesencephalon remains relatively undifferentiated, with the caudal portion contributing to the trigeminal neural crest (Fig. 9). The rhombencephalon shows a distinct isthmus and rhombomeres. The trigeminal and facioacoustic neural crests condense. The vagal and glossopharyngeal neural crests separate, with the glossopharyngeal neural crest being the larger and more differentiated. The otic plate invaginates and thickens to form the otic pit (Fig. 10).

Stage 12 (21–29 Pairs of Somites)

External Characteristics. The prosencephalon, mesencephalon, and rhombencephalon can be recognized, and the thin roof of the rhombencephalon is faintly visible. The optic vesicles appear as opaque circles. The caudal (posterior) neuropore is closing or closed.

Internal Characteristics. The prosencephalon is differentiating rapidly. The telencephalon medium begins to enlarge. The corpus striatum becomes distinct. The olfactory disc forms. The optic vesicle enlarges, emphasizing the rostral and caudal limiting sulci, and is separated from the surface ectoderm by a thin mesenchymal sheath (Fig. 11). The diencephalon is defined by sulci into



four regions: epithalamus, dorsal thalamus, ventral thalamus, and hypothalamus. The mamillary recess can be clearly identified. The mesencephalon enlarges slightly, and the marginal zone of the tegmentum (the primordia of the basis pedunculi) is evident.

Thinning of the roof of the rhombencephalon begins. The sulcus limitans between the alar and basal plates appears in the rhombencephalon of stage 12 or 13 embryos. The trigeminal primordium forms its three divisions: the ophthalmic, the maxillary, and the mandibular. The facial crest condenses, and the vestibulocochlear neural crest begins to emerge from the wall of the otic pit. The otic pit remains connected to the surface ectoderm by a small pore, and the glossopharyngeal neural crest condenses in older embryos of this stage (Fig. 12). The vagal primordium remains as an indistinct neural crest with a cranial accessory nerve extending from its caudal end. The hypoglossal nerve appears as minute sprigs emerging ventrally from the caudal rhombencephalon.

Stage 13 (30+ Pairs of Somites)

External Characteristics. The trigeminal and facial primordia can be seen as white opaque masses in translucent embryos. The otic vesicle (otocyst) with the endolymphatic diverticulum projecting dorsally can be visualized (Fig. 13).

Internal Characteristics. The olfactory disc appears as a discrete ectodermal thickening on the ventrolateral surface of the head (Fig. 14). The diameter of the telencephalon is increasing. The mesenchyme separating the optic vesicle and the ectoderm diminishes, and the contact between the ectoderm and optic vesicle is restored. The region of contacted ectoderm thickens to form the lens plate. The retinal disc swells slightly and appears to protrude into the optic cavity (Fig. 15). The marginal velum of the retinal disc is seen in older embryos of this stage.

The adeno-hypophyseal pouch epithelium thickens and extends cranially, covering a region of the floor of the diencephalon which is termed the neurohypo-

Fig. 7. Dorsal view of a stage 11 rhesus monkey embryo showing an open caudal neuropore (CN) and otic pit (OtP). $\times 18.5$

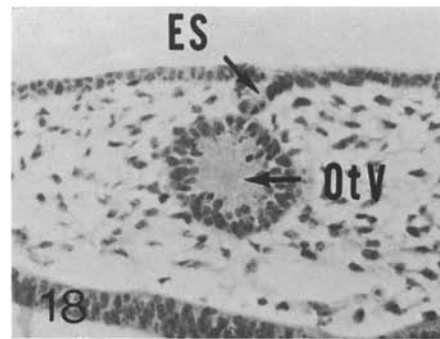
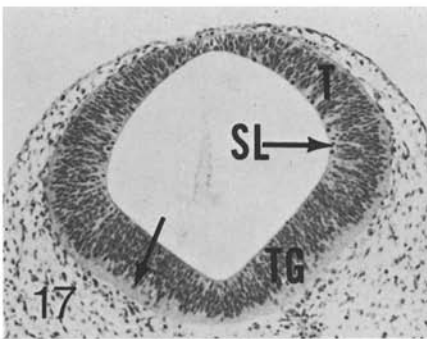
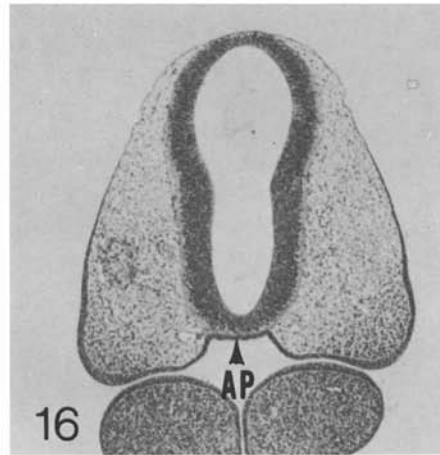
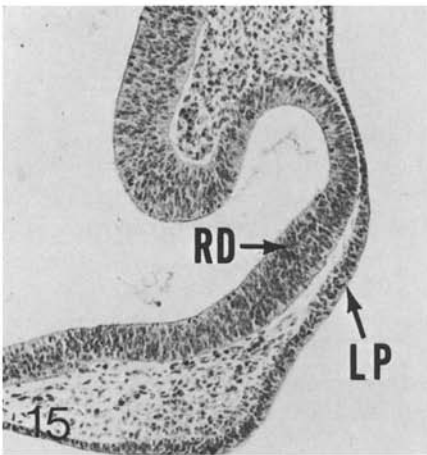
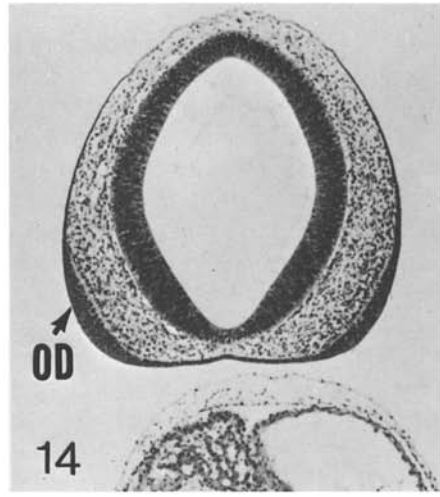
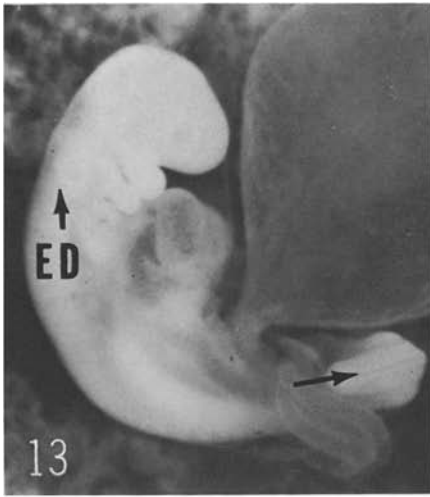
Fig. 8. Lateral view of embryo in Fig. 7 showing optic vesicle (OpV) and otic pit (OtP). $\times 18.5$

Fig. 9. Transverse section of the mesencephalon of a stage 11 baboon embryo. $\times 126$

Fig. 10. Transverse section of the rhombencephalon of stage 11 baboon embryo showing the otic pit (arrow). $\times 80$

Fig. 11. Transverse section of the diencephalon of a stage 12 baboon embryo showing the optic vesicle (OV). $\times 100$

Fig. 12. Longitudinal section of the rhombencephalon showing the pore of the otic pit (arrow) and the glossopharyngeal neural crest (GC) emerging from the postotic rhombencephalon in a stage 12 rhesus monkey embryo. $\times 100$



physeal bud area (Fig. 16). The diameter of the mesencephalon enlarges greatly. The sulcus limitans separates the tectum from the tegmentum, which at this stage shows a small but discrete marginal zone (Fig. 17).

The primordia of the ganglia of cranial nerves V, VII, VIII, IX, and X begin to form within their respective neural crests. The cranial part of the accessory nerve (XI) extends as a fibrocellular strand from the caudal region of the rhombencephalon cranially to the vagal primordium. The hypoglossal nerve rootlets extend ventrolaterally to a poorly defined collection of cells lying along the ventrolateral border of the caudal part of the rhombencephalon.

The otic pit closes, forming an otic vesicle (otocyst) connected by an ectodermal stalk to the surface (Fig. 18). In more advanced embryos of this stage, the endolymphatic diverticulum emerges as a conical outgrowth from the dorso-medial surface of the otocyst. The basement membranes of the otocyst and the rhombencephalon are in partial contact. The mesenchyme around the otocyst begins to condense to form the otic capsule.

Stage 14

External Characteristics. The telencephalon, mesencephalon, the rhombic lip, the thin roof of the myelencephalon, the lens and nasal pit, and the endolymphatic diverticulum and otocyst can be identified. A prominent mes-metencephalic sulcus can be discerned. In translucent embryos, the ophthalmic branch of the trigeminal primordium can be seen extending toward the optic cup (Fig. 19). The vagal primordium and spinal accessory nerve can also be visualized.

Internal Characteristics. The telencephalon expands rapidly, presaging the distinct formation of the cerebral vesicles in the subsequent stage. The thinning roof

Fig. 13. Lateral view of a stage 13 rhesus monkey embryo showing a closed caudal neuropore (*arrow*) and the endolymphatic diverticulum (*ED*) emerging from the otic vesicle. $\times 12$

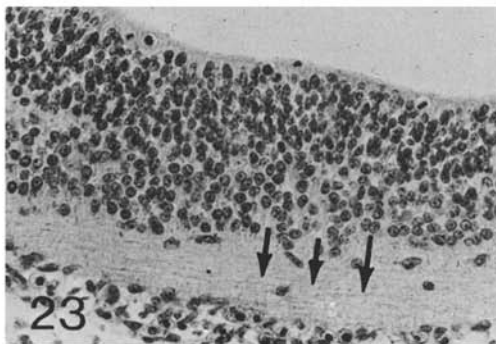
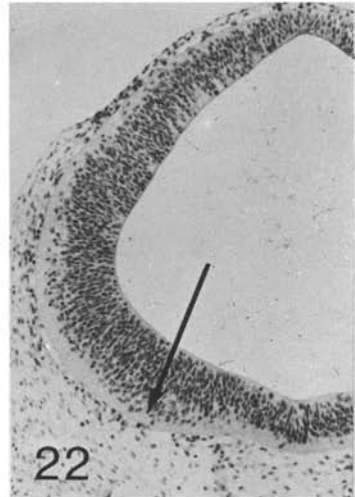
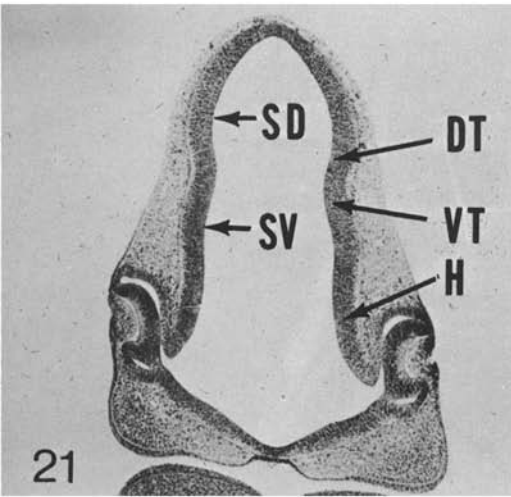
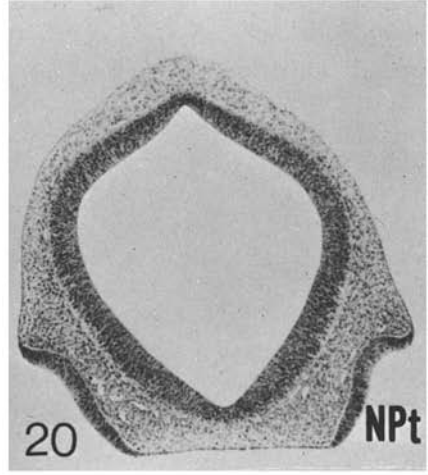
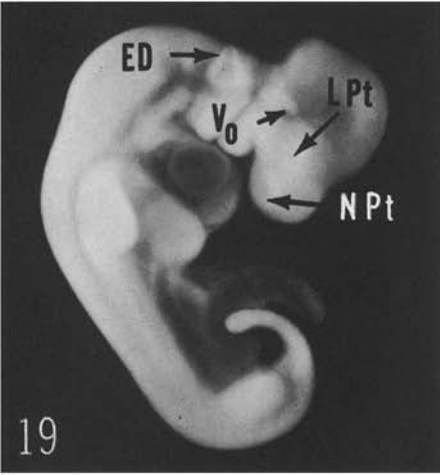
Fig. 14. Transverse section of the telencephalon of a stage 13 baboon embryo showing the olfactory disc (*OD*). $\times 48$

Fig. 15. Transverse section of the optic vesicle of a stage 13 rhesus monkey embryo showing the retinal disc (*RD*) and lens plate (*LP*). $\times 100$

Fig. 16. Transverse section through the diencephalon of a stage 13 baboon showing the adenohypophyseal pouch epithelium (*AP*). $\times 37.5$

Fig. 17. Transverse section through the mesencephalon of a stage 13 baboon showing the marginal zone (*arrow*) of the tegmentum (*TG*) and the sulcus limitans (*SL*) and the tectum (*T*). $\times 80$

Fig. 18. Longitudinal section through the rhombencephalon of a stage 13 baboon embryo showing the epidermal stalk (*ES*) attached to the otic vesicle (*OtV*). $\times 200$



of the telencephalon marks the site of the velum transversum. In advanced embryos the olfactory disc thickens and becomes indented, and olfactory fila appear (Fig. 20). The corpus striatum begins to bulge into the cavity of the lateral ventricle as neuroblasts proliferate into a mantle layer. A substantial marginal zone appears in the thalamic wall, and the sulcus ventralis (hypothalamic sulcus) is distinct (Fig. 21). The adeno-hypophyseal pouch becomes more constricted from the pharyngeal roof and forms a double-walled, cuplike structure.

The optic cup and retinal (choroid) fissure form by invagination of the retinal disc. Concomitantly, the lens plate invaginates, forming the lens pit. The lens pore closes in the baboon but remains open in the rhesus monkey embryo. The primary vitreous body begins to form.

The mesencephalon shows a rapid increase in size from the preceding stage. A slight marginal zone appears in the tectum, which is beginning to differentiate. The area of the basis pedunculi of the tegmentum begins to enlarge and has marked neuroblastic proliferation medial to it (Fig. 22). Neuroblasts of cranial nerves III and IV differentiate and concomitantly the nerve rootlets of III (oculomotor) emerge from the ventrolateral margin of the tegmentum.

The pontine flexure is prominent. The pons area enlarges as the pyramidal tract area forms, and the marginal zone begins to enlarge as motor and sensory roots form and their axons invade it (Fig. 23). Motor and sensory roots of cranial nerves V to X form during stages 14 and 15. The abducens (VI) emerges as a collection of rootlets from the ventrolateral border of the pons. The ganglia of the vestibulocochlear and facial nerves are becoming more discrete. The chorda tympani and greater petrosal branches of the facial nerve can be identified in advanced embryos. The glossopharyngeal and vagal primordia form superior and inferior ganglia. The vagal primordium is now larger than the glossopharyngeal primordium.

The otic vesicle enlarges, and its walls show differential thickening. The elongating endolymphatic diverticulum is set off from the future utricular portion of the otic vesicle by the developing utriculo-endolymphatic fold.

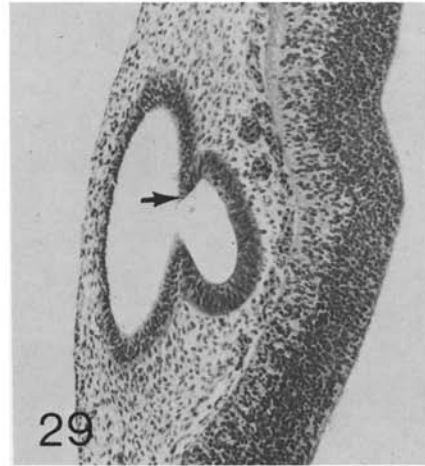
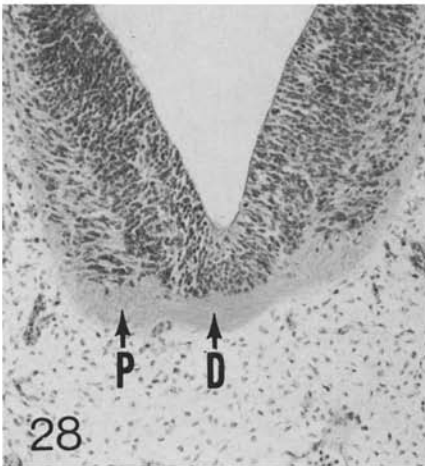
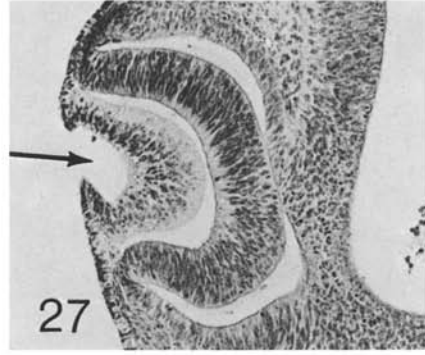
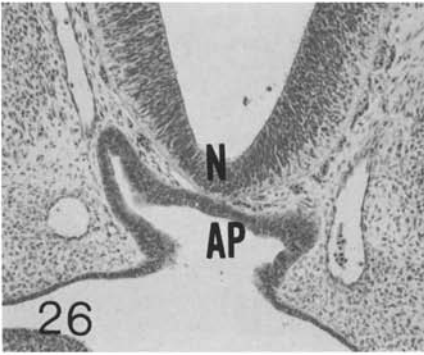
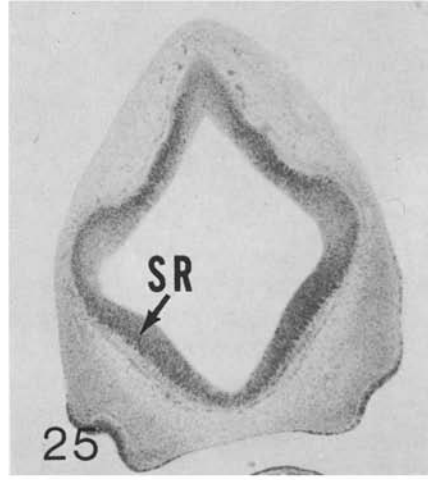
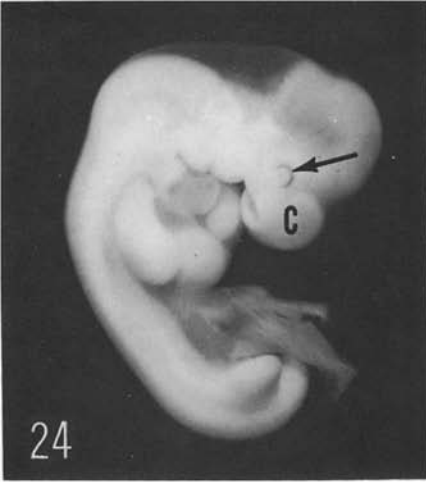
Fig. 19. Lateral view of a stage 14 rhesus monkey embryo showing the nasal (*NPt*) and lens (*LPt*) pits and a prominent endolymphatic diverticulum (*ED*). The ophthalmic branch (*Vo*) of the trigeminal ganglion can be clearly visualized. $\times 6$

Fig. 20. Transverse section of the telencephalon of a stage 14 rhesus monkey embryo showing the nasal pit (*NPt*). $\times 37.5$

Fig. 21. Transverse section of the diencephalon of a stage 14 rhesus monkey embryo showing the sulcus dorsalis (*SD*) and sulcus ventralis (*SV*), dorsal (*DT*) and ventral (*TH*) thalamus and the hypothalamus (*H*). $\times 30$

Fig. 22. Transverse section of the mesencephalon of a stage 14 rhesus monkey embryo showing the area of the enlarging basis pedunculi of the tegmentum (*arrow*). $\times 80$

Fig. 23. Longitudinal section of the rhombencephalon at the level of the pons of a stage 14 rhesus monkey embryo showing pyramidal tract fibers coursing longitudinally (*arrows*). $\times 200$



Stage 15

External Characteristics. The cerebral hemispheres have expanded prominently. The roof of the myelencephalon flattens. The nasal pits deepen on the lateral surface. Retinal pigment is visible (Fig. 24). The vagus and accessory nerves seen in stage 14 embryos can now be clearly distinguished.

Internal Characteristics. The corpus striatum continues to enlarge as neuroblasts proliferate and the marginal zone (primordial tuberculum olfactorium) expands. The primordia of the lateral striatal (amygdaloid) elevations appear as a thickened striatal ridge at the basal portions of the cerebral vesicles (Fig. 25). The olfactory fila become distinct and extend toward the ventral surface of the cerebral vesicles. The pineal bud (epiphysis cerebri) can be recognized in the epithalamus during this stage, becoming more prominent by stage 16. Neuroblasts begin to proliferate in the hypothalamus and ventral thalamus. The neurohypophysis begins to evaginate from the floor of the diencephalon. The caudal portion of the adenohypophyseal pouch forms a distinct double-layered cup around the ventrostral portion of the evaginating neurohypophysis in stages 15 and 16 (Fig. 26).

Pigment granules form in the external (pigmented) layer of optic cup. The rhesus monkey lens pit is closing or closed during this stage (Fig. 27). The lens vesicle forms as the lens pit closes, remaining in contact with the surface ectoderm. The primary lens fibers are seen in the deep wall of the lens. The restored surface ectoderm constitutes the anterior epithelium of the future cornea. The optic stalk is now evident.

In the mesencephalon, the marginal layer of the tectum becomes continuous dorsally. Ventrally the oculomotor (III) nerve forms discrete fascicles. The trochlear nerve (IV) decussates dorsally and nerve fibers form during stage 15. The decussation of the pyramids of the rhombencephalon is apparent (Fig. 28).

Fig. 24. Lateral view of a stage 15 rhesus monkey embryo showing a cerebral hemisphere (*C*) and retinal pigment (*arrow*). $\times 7$

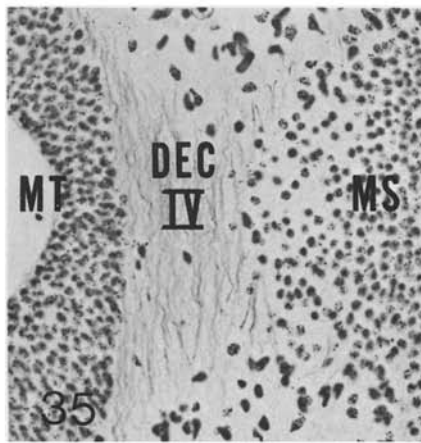
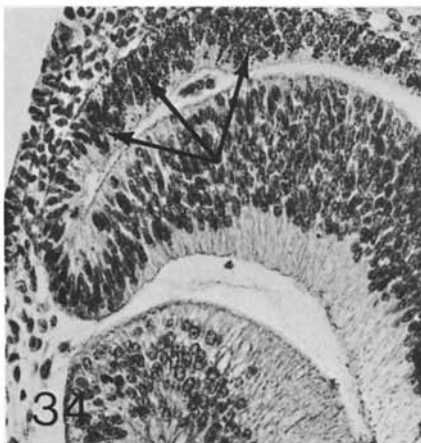
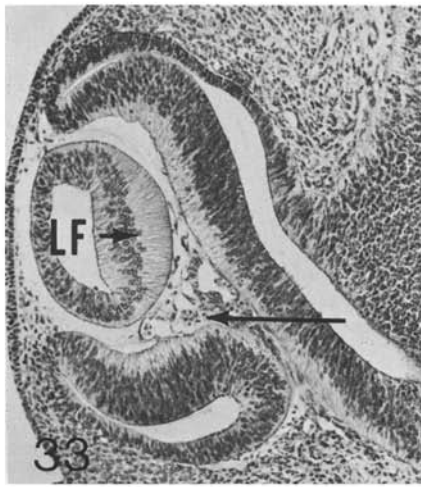
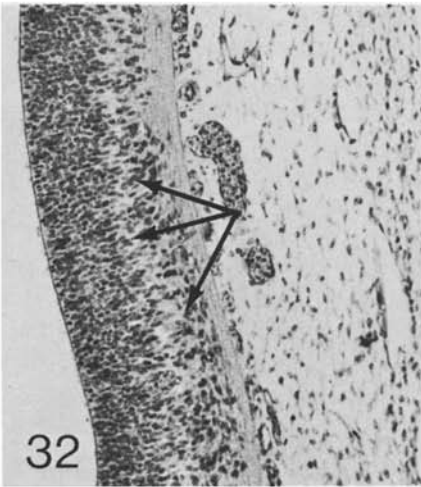
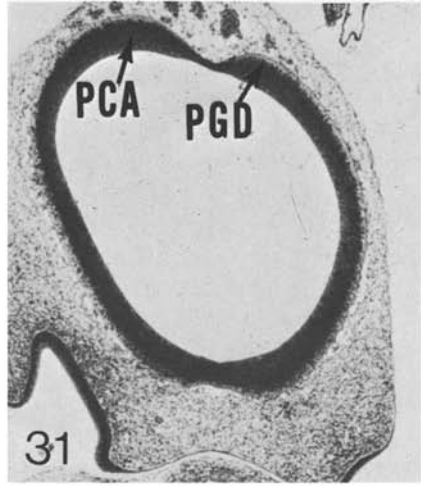
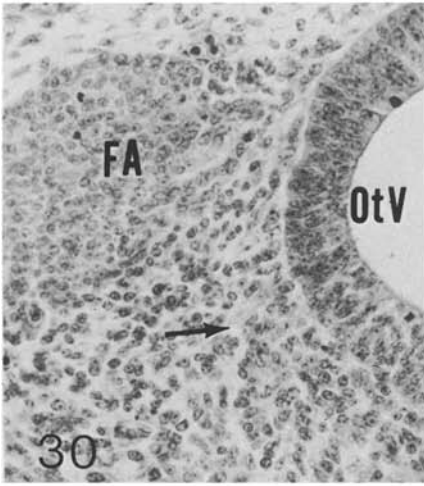
Fig. 25. Transverse section of the telencephalon of a stage 15 rhesus monkey embryo showing a thickened striatal ridge (*SR*). $\times 31$

Fig. 26. Transverse section of the diencephalon of a stage 15 rhesus monkey embryo showing the adenohypophyseal pouch (*AP*) and the neurohypophyseal bud (*N*). $\times 80$

Fig. 27. Transverse section of the optic cup of a stage 15 rhesus monkey embryo showing the open lens pore (*arrow*). $\times 100$

Fig. 28. Transverse section of the rhombencephalon of a stage 15 rhesus monkey embryo showing the decussation (*D*) of the pyramids (*P*). $\times 100$

Fig. 29. Longitudinal section of the rhombencephalon of a stage 15 rhesus monkey embryo showing the utriculo-endolymphatic fold (*arrow*). $\times 100$



The cochlear and vestibular pouches are distinct. The endolymphatic duct is distinct and forms from the medial surface of the otocyst. The utriculo-endolymphatic fold is pronounced (Fig. 29). The tip of the otic vesicle represents the future cochlear duct. The cochlear and the vestibular ganglia and the vestibulo-cochlear nerve form. Neuroblasts differentiate in the ganglia of the cranial nerves in stages 15 and 16 (Fig. 30). The geniculate ganglion is distinct and the motor root of the facial nerve forms. The superior and inferior ganglia of the glossopharyngeal and vagus nerves are discrete. The tympanic branch of the glossopharyngeal nerve and the superior laryngeal and inferior (recurrent) laryngeal branches of the vagus nerve appear. The cranial part of the accessory nerve becomes part of the recurrent laryngeal nerve.

Stage 16

External Characteristics. The nasal pits face ventrally as the lateral nasal processes develop. Retinal pigment can be seen in the translucent embryos during stage 16.

Internal Characteristics. The primordial gyrus dentatus and cornu Ammonis of the hippocampal formation appear in stages 15 and 16 (Fig. 31). No internal sulcus (sulcus limitans hippocampi) is seen. The olfactory fila contact the ventral surface of the cerebral vesicles. The intermediate zone forms in the ventral thalamus and hypothalamus during stage 16 (Fig. 32). A rapid cellular proliferation appears in the mammillary body during stages 15 and 16. The neurohyphysis forms a fingerlike ventral projection in advanced embryos.

The body of the lens vesicle enlarges, and more intracellular pigment granules appear in the external layer of the optic cup. The retrolental blood vessels are prominent (Figs. 33 and 34).

In the mesencephalon the tectum enlarges as axons appear in the marginal zone. The dorsally decussating trochlear nerve is distinct in this stage (Fig. 35).

Fig. 30. Longitudinal section of the facioacoustic (*FA*) ganglion in a stage 15 rhesus monkey embryo showing fibers (*arrow*) from differentiating neuroblasts coursing towards otic vesicle (*OIV*). $\times 230$

Fig. 31. Transverse section of the telencephalon in a stage 16 baboon embryo showing the primordia of the cornu Ammonis (*PCA*) and gyrus dentatus (*PGD*). $\times 37$

Fig. 32. Transverse section of the diencephalon of a stage 16 rhesus monkey embryo showing the intermediate zone (*arrows*) in the ventral thalamus. $\times 110$

Fig. 33. Transverse section through the optic cup of a stage 16 rhesus monkey embryo showing primary lens fibers (*LF*) and retrolental blood vessels (*arrow*). $\times 92$

Fig. 34. Transverse section through the optic cup of a stage 16 rhesus monkey embryo showing pigment granules in the external layer of the optic cup (*arrows*). $\times 230$

Fig. 35. Transverse section showing the dorsal decussation of the trochlear nerve (*DECIV*) at the isthmus separating the mesencephalon (*MS*) and the metencephalon (*MT*) in a stage 16 baboon embryo. $\times 230$

The pyramidal zone enlarges in the rhombencephalon. Differential thinning of the walls of the otocyst presage the appearance of the semicircular canals while the endolymphatic diverticulum continues elongation. The nasociliary nerve forms from the maxillary branch of the trigeminal nerve.

Discussion

Although morphogenesis of the brain and its derivatives is quite similar in the baboon, rhesus monkey, and human embryo during the stages of development studied, the variation in embryonic age between these species for each stage of development must be borne in mind. Data presently available for baboon and rhesus monkey embryos (Hendrickx et al. 1971; Hendrickx and Sawyer 1975) indicate that these species are essentially equal in embryonic age during stages 1 to 8 and stages 15 to 23 of the embryonic period. However, the rhesus monkey embryo appears to be approximately two days younger than the baboon embryo during stages 9 to 14. Data collected from a variety of sources and presented in tabular form by O'Rahilly for the human (1973) indicate that the embryonic age of the human embryo equals or is slightly younger than that of baboon and rhesus monkey embryos during stages 1 to 11, and that from stages 12 to 23 of the embryonic period the embryonic age of the human embryo is consistently greater than that of baboon and rhesus monkey embryos. Therefore, it should be stressed that comparisons between these species involving neural or other embryonic organ systems be made on the basis of embryonic stage rather than embryonic age.

In contrast with the human (Streeter 1948; O'Rahilly 1966) and baboon (Hendrickx et al. 1971) embryos, closure of the lens pore in the rhesus monkey embryo is not a reliable criterion for differentiating stage 14 embryos from stage 15 embryos. Lens pore closure appears to lag behind other normally differentiating structures within the nervous and other organ systems characteristic of stage 15 baboon and human embryos. Consequently, stage 15 rhesus monkey embryos are best described as having lens pores that are closing or closed.

Table 2. Differences in neurological development of rhesus monkey, baboon, and human embryos (stages 8–16)

Developmental event	Embryonic stage		
	Baboon	Rhesus monkey	Human
Otic disc formation	10	10	9
Adenohypophyseal pouch	11–12	11–12	10
Trigeminal primordium	12–13	12–13	14
Motor root, trigeminal	14	14	15
Lens pore closure	14	15	14
Neurohypophyseal evagination	15	15	16
Internal sulcus (hippocampus)	later than 16	later than 16	15

During stages 14, 15, and 16, the elongation of the endolymphatic diverticulum in the rhesus monkey is similar to that in the human and far more rapid than in the baboon.

Other major differences are shown on Table 2.

Their overall similarity to man in the temporal aspects of early brain development indicates that either the baboon or the rhesus monkey would serve as a suitable animal model for further studies of normal and abnormal development.

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