slower changes in membrane potential characteristic of synaptic potentials. In addition, four of the seven double-labeled cells responded to the onset or offset of auditory stimuli with depolarizing synaptic potentials at latencies of 26 to 32 msec (Fig. 1B). We have not yet determined whether any of the double-labeled cells form synapses on other HVc cells, though the presence of axonal arbors within HVc suggests this. The double-labeled neurons we have described may constitute a category of local interneurons, some of which are sensitive to acoustic stimuli. This hypothesis is supported by preliminary experiments in which none of the neurons whose axons leave the HVc (identified by retrograde labeling with HRP) were radioactively labeled after [^{3}H]thymidine treatment similar to that used in the present experiments (*15*).

The evidence presented here constitutes a direct demonstration of central nervous system cells that are generated in adulthood, adopt a neuronal morphology, show synaptic and action potentials, and are recruited into functional brain circuits. Though the likelihood of such a series of events has been accepted for fish, whose body and brain continue to grow in adulthood (*16*), the proof offered here establishes that neurogenesis can occur in a vertebrate brain well after it has achieved its full adult size. Thus the question can no longer be whether this phenomenon exists, but rather how it comes about, why is it so rarely found, and what is its significance?

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Flying Squirrels Are Monophyletic

Abstract. *Seven genera of flying squirrels share five characters of wrist anatomy, which form a functional complex associated with the support of the patagium. In these characters, they differ from all genera of tree and ground squirrels examined. Among mammals, gliding membranes have evolved independently in several other groups. The manner of attachment of the patagium to the forelimb is different in each and demonstrates five morphologies differing from that of flying squirrels. This complex wrist anatomy of flying squirrels provides evidence that gliding evolved only once among squirrels and that the flying squirrels are a monophyletic group.*

Several investigators have proposed that the flying squirrels (Petauristinae) are a polyphyletic group (*1*), consisting of genera derived from Southeast Asian tree squirrels (Callosciurini) and from Holarctic tree squirrels (Sciurini). Other investigators have suggested that flying squirrels evolved from a subfamily of paramyid rodents, different from that of tree squirrels (*2*, *3*), and hence that the family Sciuridae is polyphyletic. Although recent classifications ignore these arguments and include all squirrels in a single family, the Sciuridae (*4*), the arguments for polyphyly have gone unchallenged.

The hypothesis that flying squirrels are not derived from tree squirrels is based on the observation that they were as diverse in the Miocene as they are at present and the supposition that this diversification required a long period of evolution after the flying squirrels diverged from the tree squirrel lineage (*2*, *3*). The earliest fossil thought to be a flying squirrel (*Paracitellus* sp. A. Dehm) dates from the Burdigalian, approximately 17 million years ago (*5*). However, the oldest known fossil tree squirrel, *Protosciurus*, dates from the Chadronian Oligocene, about 35 million years ago (*6*), so that there remains a period of almost 20 million years during which flying squirrels could have evolved and radiated from an ancestral tree squirrel. This alternative hypothesis is supported by the presence of several shared derived features in modern tree squirrels and flying squirrels, such as the sciuromorphous jaw musculature, morphology of the ear region, and the presence of a subscapular spine. Sciuromorphy was not fully developed in *Protosciurus*, although the postcranial anatomy is remarkably similar to that of the North American fox squirrel *Sciurus niger* (*6*). Therefore the simplest hypothesis is that flying squirrels evolved from a tree squirrel ancestry sometime after the Chadronian, 35 million years ago (*7*).

All flying squirrels have a patagium supported at the wrist by a styliform cartilage (*8–10*), which attaches to the pisiform bone. The ulnar carpal flexor muscle attaches to the base of the styliform cartilage and functions to fold the cartilage and the gliding membrane against the forearm when the squirrel is not gliding. The styliform cartilage and the gliding membrane are extended by the abductor pollicis muscle, which inserts on the small falciform bone in the palm of the hand, which in turn connects by a ligament to the base of the styliform cartilage. This morphology results in maximum extension of the wing tip of the gliding membrane when the hand is dorsiflexed and medially deviated, as can be seen in photographs of gliding squirrels (*11*, *12*).

The morphology of the wrist joint of flying squirrels (*13*) shows specializations associated with its function in gliding (Fig. 1). The pisiform bone articulates both with the triquetrum and also with the scapholunate. This articulation with the scapholunate, which would appear to function as a stabilizer of the pisiform and hence of the styliform cartilage, was not found in any other squirrels examined (*11*). The joint surface between the ulna and the triquetrum has a

different orientation in flying squirrels from that seen in tree squirrels, with the triquetral facet facing more laterally in flying squirrels. The articular surface between the radius and the scapholunate differs also. In tree squirrels the articular surface of the scapholunate is planoconvex, like a section from a column, whereas in flying squirrels it is convexoconvex, like a part of a sphere. These differences in the articular surfaces allow greater medial deviation of the hand in flying squirrels, the position taken when they are gliding.

In flying squirrels there is a strong, extensive syndesmosis of the distal radius and ulna (*14*) (Fig. 2) which prevents movement between them at the wrist joint and would appear to stabilize the joint. The syndesmosis is relatively longer in small flying squirrels (48 ± 2.4 percent of the length of the radius in 19 *Glaucomys sabrinus*) than in large ones (25 percent in four *Petaurista petaurista*). In tree squirrels the distal articulation of the radius and ulna is much less extensive and is mobile. In spite of the absence of movement between the radius and ulna at the wrist, flying squirrels can pronate and supinate their forearms, something which humans cannot do if the distal ends of the radius and ulna are pinned together. Flying squirrels accomplish this by rotating the ulna relative to the humerus at the elbow joint; some torsion of the thin ulna may also occur. Rotation of the radius is accomplished by the supinator and pronator teres muscles. Rotation of the ulna appears to be effected by the medial anconeus muscle (*15*). The pronator quadratus muscle is absent in flying squirrels (*16*). Pronation and supination are accomplished similarly in tree squirrels, except that a pronator quadratus muscle is present and no torsion of the ulna is possible.

In summary, flying squirrels share a series of functionally related characters, including (i) the presence of a styliform cartilage attached to the pisiform, (ii) the articulation of the pisiform to the scapholunate, (iii) the orientation of the ulnar-triquetral joint, (iv) the shape of the radioscapholunate joint, and (v) an extensive syndesmosis between the distal ends of the radius and ulna, with absence of the pronator quadratus muscle. All other squirrels studied differ from flying squirrels in these five characters (*13*). The Oligocene fossil tree squirrel *Protosciurus* is like the modern tree squirrels in all these characters. Therefore, it seems likely that these musculoskeletal characters of flying squirrels are derived and evolved only once among squirrels.

Could the same morphology have evolved more than once as an evolutionary adaptation to the exacting requirements of gliding flight? Examination of other gliding mammals shows this to be improbable. The flying lemurs (Dermoptera) are "mitten gliders," with the gliding membrane extending around the hand and with webbing between the digits. The marsupial sugar gliders (*Petaurus*) are "finger gliders," the membrane extending to the tip of the little finger but without webbing between the digits. The pygmy glider (*Acrobates*) has the membrane extending from the wrist to the ankle, as in the flying squirrels, but it lacks a cartilaginous support for the membrane at the wrist. A third marsupial glider, *Schoinobates*, is an "elbow glider," with the membrane extending only to the elbow. It glides with its forearms flexed—elbows out and hands under the chin—unlike any other gliders. The scaly-tailed "flying squirrels" (Anomaluridae) are also "elbow gliders," but the gliding membrane is supported by a cartilage at the elbow and the animals glide with forelimbs extended. Thus there are six ways in which gliding mammals support the gliding membrane on the forelimb. The anatomy of the flying squirrels (Petauristinae) is unique and the gliding position is peculiar; all other gliding mammals hold their hands parallel to the plane of the gliding membrane. Only flying squirrels hold them perpendicular (*13, 17*).

For the evidence presented, the most simple hypotheses are that squirrels (Sciuridae) form a monophyletic group, that flying squirrels (Petauristinae) are monophyletic and evolved from a tree squirrel, and that flying squirrels evolved from tree squirrels during the Oligocene after the Chadronian.

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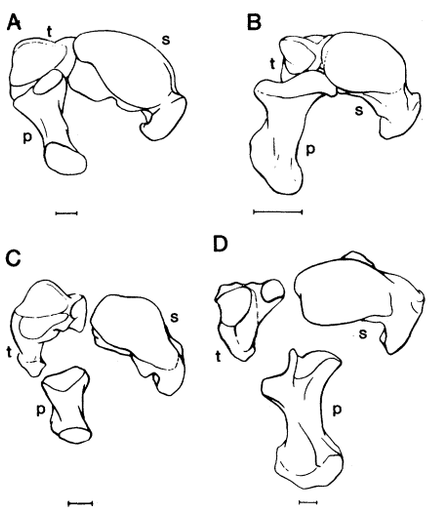

Fig. 1. Proximal carpal bones of squirrels. (A) Fox squirrel (*Sciurus niger*). (B) Southern flying squirrel (*Glaucomys volans*). (C) Red-bellied tree squirrel (*Callosciurus erythraeus*). (D) Giant flying squirrel (*Petaurista petaurista*). Key: *s*, scapholunate; *t*, triquetrum; *p*, pisiform. Scale is 1 mm.

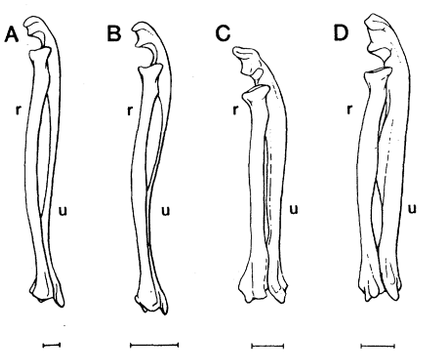

Fig. 2. Radius and ulna of squirrels. (A) Giant flying squirrel (*Petaurista petaurista*). (B) Southern flying squirrel (*Glaucomys volans*). (C) Red-bellied tree squirrel (*Callosciurus erythraeus*). (D) Eastern gray squirrel (*Sciurus carolinensis*). Key: *r*, radius; *u*, ulna. Scale is 5 mm.

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tae sedis: *Sciurotamias*. These represent all tribes of the subfamily recognized by J. C. Moore [*Am. Mus. Nat. Hist.* **118**, 153 (1959)]. Flying squirrels examined were *Glaucomys*, *Eoglaucomys*, *Iomys*, *Petaurista*, *Aeromys*, *Trogopterus*, *Pteromyscus*, and *Petinomys*, representing all generic groups of Petauristinae proposed by M. C. McKenna [*Am. Mus. Novit.* **2014**, 1 (1962)] and P. Mein (*3*).

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15. Rotation of the ulna by the epitrochlea-anconeus muscle was proposed by J. W. Hultkrantz [*Das Ellbogengelenk und seine Mechanik* (Fischer, Jena, 1897)] and supported by R. W. Haines [*J. Anat.* **84**, 13 (1950)]. A. B. Howell [*J. Morphol.* **60**, 287 (1936)] and W. L. Straus, Jr. [*J. Anat.* **70**, 281 (1942)] have argued that the muscle only fixes the elbow joint. Supination of the forearm can be demonstrated in a freshly killed *Glaucomys*, with rotation of approximately 40°, accompanied by rotation of the ulna on the trochlear surface of the humerus. An illustration of a living *Glaucomys* with forearms supinated, probably more than 40°, is to be found in E. P. Walker (*11*).
16. The pronator quadratus muscle was reported to be present in *Glaucomys* by H. E. Peterka (*9*); it was not found in specimens dissected by M. D. Bryant (*10*) or by me (*Glaucomys*, *Petinomys*, *Pteromyscus*).
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Prostaglandin E_2: A Neuromodulator in the Central Control of Gastrointestinal Motility and Feeding Behavior by Calcitonin

Abstract. *Two micrograms of prostaglandin E_2 injected into the lateral ventricle of the brain in rats had the same anorectic and gastrointestinal motor effect as central administration of 0.02 unit of calcitonin. The effects of calcitonin were blocked by a previous intracerebroventricular administration of 0.25 milligram of indomethacin. These results suggest that both anorectic and gastrointestinal motor effects of calcitonin are centrally mediated by the release of prostaglandins.*

Prostaglandins mediate the responses at neuroendocrine junctions in the preoptic area of the anterior hypothalamus that are involved in thermoregulation and fever. There is now evidence that prostaglandins are also involved in other neuroendocrine responses (*1*). For instance, intracerebroventricular administration of prostaglandin E_2 (PGE_2) causes tachycardia and a rise in blood pressure (*2*), confirming that the pressure response to parenteral PGE_1 and PGE_2 is partially mediated by the central nervous system (*3*). This pressure response has been attributed to a prostaglandin-induced activation of adrenergic or cholinergic neurons rather than being considered a reflex reaction to the prostaglandin-induced hyperthermia (*4*). Prostaglandins also participate in the regulation of hypothalamic (*5*) and adenohypophyseal hormone secretions (*6*), and centrally administered prostaglandins affect gastrointestinal function; prostaglandins inhibit forestomach motility in the goat (*7*) and insulin-stimulated gastric acid secretions in rats (*8*) and cause anorexia in rats (*9*).

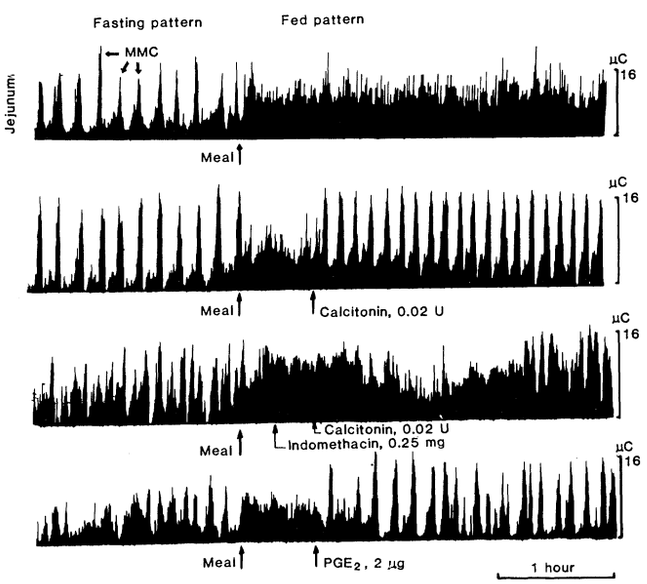

Fig. 1. Influence of intracerebroventricular administration of calcitonin (0.02 unit) with or without previous intracerebroventricular treatment with indomethacin (0.25 mg) and PGE_2 (2 µg) on the pattern of electrical activity (integrated record) of the small intestine (jejunum) in rats (vertical scale in microcoulombs). In food-deprived rats, the pattern of electrical activity is organized in cyclic migrating myoelectric complexes that were disrupted for 6 to 8 hours after feeding (fed pattern). Both calcitonin and PGE_2 restored the fasting pattern in the fed rat, and this effect was blocked by previous treatment with indomethacin.

Gastrointestinal secretory (*10*) and motility (*11*) responses, as well as feeding behavior (*12*), are now known to be mediated by neuropeptides in the brain. Calcitonin injected intracerebroventricularly in picomolar doses restores the fasting pattern of motility in fed rats (*13*), reduces gastric acid secretion (*14*), and produces anorexia in rats (*15*). Our results show that intracerebroventricularly administered PGE_2 and calcitonin have similar effects on intestinal motility and feeding behavior. This suggests that the effects of calcitonin are centrally mediated by the release of prostaglandins within the brain.

These experiments were performed in two series to investigate, respectively, the digestive motor profile and feeding behavior of rats. In the first series of experiments, 12 male Wistar rats weighing 250 to 350 g were prepared for long-term electromyographic recording of intestinal motility with implanted Nichrome wires (diameter, 80 µm) placed on the duodenojejunum at 5, 30, and 60 cm from the pylorus. The electrode wires, 60 cm in length, were exteriorized on the back of the neck. In addition, a small polyethylene catheter was inserted into the right lateral ventricle of the brain (*16*).

Electrical activity of the small intestine was recorded twice per week with an electroencephalograph (Reega VIII Alvar, paper speed 2.4 cm/min) in rats deprived of food for 12 hours. The identification of the motility pattern was facilitated by summing the spiking activity every 20 seconds; this gave an integrated record of the myoelectrical activity, which was recorded on a chart recorder at a slow paper speed (6 cm/hour).

After 2 hours of control recordings and 40 minutes after the beginning of a meal consisting of 6 g of a balanced laboratory ration, 5 µl of sterilized water either alone or containing 0.02 unit (1 unit = 208 ng) of salmon calcitonin (Calsyn) was injected intracerebroventricularly twice in each rat. Similar injections were given 20 minutes after intracerebroventricular administration of 0.25 mg of indomethacin dissolved in 10 µl of 5 percent $NaHCO_3$. The rats also received an intracerebroventricular injection of 2 µg of PGE_2 (Upjohn) dissolved in 5 µl of