Table 1 Relative intensities of the mass spectral peaks of the thermal decomposition products.

Toluene complex 150° C		*p*-xylene complex 150° C		*trans*-stilbene complex 200° C	
m/e	Intensity	*m/e*	Intensity	*m/e*	Intensity
272	17	315	12	450	2
270	18	314	26	449	3
257	18	300	11	372	1
255	20	299	38	370	2
195	10	249	24	360	92
182	13	210	42	346	8
181	19	209	35	344	5
167	16	195	59	280	18
165	23	193	42	279	12
105	25	119	41	270	65
92	62	118	56	269	73
91	106	106	68	252	18
		105	100	239	8
				203	9
				202	13
				191	69
				180	77
				179	76
				178	100

respective aromatic material. Excess *trans*-stilbene was removed by washing with chloroform, and surplus solvent was removed by suction. On heating the complexes *in situ* in an AEI MS30 mass spectrometer, in high vacua, between 50 and 250° C, high molecular weight products appeared.

With the benzene complex of Cu(II) montmorillonite, which is known to involve the second type of linkage between the metal and the aromatic ring, only a negligible proportion of material possessing a molecular weight approximately two or three times that of benzene was produced, whereas with the toluene complex, which has the first type of linkage, appreciable quantities of molecules of mass number 272 and 182 were formed (Table 1). These mass numbers correspond to three toluene units less four hydrogen atoms and to two toluenes less two hydrogens, respectively. Complexes of all three xylenes, which have similar copper–arene linkages to the toluene complex, behaved very similarly and yielded mass numbers of 314 and 210, again signifying the loss of hydrogens when three and two units, respectively, of xylene condense. Blank mass-spectrometric experiments carried out with sodium-ion-exchanged montmorillonite revealed that, essentially, no hydrocarbon of higher molecular weight was formed when traces of physically adsorbed alkyl benzene were heated in the absence of the transition-metal ion.

With *trans*-stilbene, the results were strikingly different in that significant quantities of material possessing a mass number of 360, which corresponds to the dimer, were obtained. (Some ions with *m/e* equal to 370–450 were observed in low abundance, so some trimer or even higher order species must have been formed, although the molecular ion(s) corresponding to such species were not observed.)

Although much remains to be learned about the mechanisms of these thermally induced reactions the obvious major difference in the nature of the products obtained suggests that different reaction pathways are followed depending on whether the organic molecules contain aromatic rings or aromatic rings together with ethylenic double bonds. The implication, which needs to be tested, is that the central olefinic double bond in *trans*-stilbene is bonded to the Cu ion and that, as a result of the proximity and the electronic perturbation of these olefinic double bonds of the two (or more) *trans*-stilbene molecules, dimerisation is facilitated. Though it is unnecessary to postulate that the dimerisation is concerted, it is of interest to note that the thermal production of tetraphenyl-cyclobutane from *trans*-stilbene monomers is, by orbital symmetry, forbidden and that the photochemical dimerisation, though allowed, is not easily achieved either in the solid state[8,9] or when weakly physically adsorbed[10].

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Systematic position of *Plesiadapis*

The systematic position of the Palaeocene mammal *Plesiadapis* has been a subject of discussion for almost a century. This is not surprising considering the meagre evidence on which it was first associated with lemuroid primates. A review of the evidence now available indicates that the affinities of *Plesiadapis* and its relatives are with early tarsier-like primates, and not with archaic lemurs.

Gervais[1] described the genus *Plesiadapis* after he[2] and Delfortrie[3] had recognised *Adapis* as a primate related to living lemurs. Gervais' species *Plesiadapis tricuspidens* was originally based on two specimens collected by Lemoine from the Palaeocene of France—a mandible fragment and an isolated incisor—neither of which show any significant resemblance to *Adapis*. The relationship between *Plesiadapis* and *Adapis* advocated by Gervais was apparently based on several Eocene specimens first described by Lemoine as *Plesiadapis*[4], but subsequently transferred to the new genus *Protoadapis*[5] (which is closely related to *Adapis*).

Once given a name compounded from *Adapis*, no matter how poorly justified that actually was, it is natural that *Plesiadapis* was subsequently compared most closely with lemur-like primates. Simpson[6] emphasised the detailed resemblance of the molar pattern of *Plesiadapis* to that of the early adapid *Pelycodus*, and classified the Plesiadapidae as a family within the Lemuroidea[7]. The presence of a postprotocingulum ('*Nannopithex*-fold') on the upper molars of *Plesiadapis*, *Pelycodus*, and early Eocene tarsioid primates is an important derived characteristic shared by early primates[8] but, considering the important differences now known in the anterior dentition of species of *Plesiadapis* and *Pelycodus*, it appears that Simpson overestimated the significance of their molar resemblances. *Plesiadapis* also differs significantly in middle ear structure from early lemuroid primates.

In a group of mammals with a reasonably good fossil record, a biostratigraphic approach to phylogeny[9] offers the best evidence for working out the true relationships between species. Virtually all specimens assigned to the family Plesiadapidae have been studied again in a carefully documented biostratigraphic context[10]. Five plesiadapid lineages are known, at least two of which were common to both Europe and North America. Particularly interesting here is the major lineage leading from *Pronothodectes matthewi* of the middle Palaeocene (Torrejonian) to *Platychoerops richardsonii* of the early Eocene (Cuisian).

Plesiadapis tricuspidens is a late member of this central lineage. As the earliest plesiadapid and the common ancestor of all the later species known, *Pronothodectes* is the primitive form which should be compared with members of other families in determining the relationships of Plesiadapidae.

Pronothodectes matthewi is similar in dental conformation to early species of Carpolestidae, Paromomyidae, and Microsyopidae (Paromomyidae is limited here to forms having tricuspid plesiadapid- or carpolestid-like upper incisors, including *Paromomys*, *Phenacolemur*, and possibly *Saxonella*; whereas the Microsyopidae, including *Plesiolestes*[11], *Palaechthon*, *Palenochtha*, *Berruvius*, *Navajovius*, have simpler bicuspid upper incisors[10].) All have a basic dental formula of

$$\frac{2}{2}\cdot\frac{1}{1}\cdot\frac{3}{3}\cdot\frac{3}{3}$$

and all have enlarged, procumbent, pointed, lower central incisors. Early Tarsiidae and Omomyidae have the same basic dental formula and very similar lower incisors, with one possible exception: some specimens of *Teilhardina* apparently retained four premolars, although descriptions of the dental morphology of this genus are conflicting and deserve additional study. The lower dental formula of microchoerines is sometimes cited as 1.1.4.3 (ref. 12), but interstitial wear on the medial side of the enlarged anterior tooth shows it to be the central incisor, and the 'alveolus' in front of this tooth is an anterior mental foramen[10].

Figure 1 shows that the mandibular and dental conformation of Palaeocene primates of the infraorder Plesiadapiformes is very much like that of Eocene Tarsiiformes (Plesiadapiformes Simons, 1972[13] includes the same four families as Paromomyiformes Szalay, 1973[14] and the former name is used here). The morphology of the anterior teeth differs fundamentally from that seen in the earliest lemuroid primate *Pelycodus* and its descendants. The lower central incisor (I_1) of *Pelycodus* is slightly smaller than I_2 and both are considerably smaller than the canine. Furthermore, the incisors of adapids differ in being vertically implanted and in having spatulate rather than pointed crowns.

The auditory bulla and middle ear are exceptionally well preserved in a skull of *Plesiadapis tricuspidens* recently collected by M. Pellouin of Reims from the Palaeocene locality of Berru in France. The auditory bulla in this skull was completely ossified, with no trace of a separate entotympanic element (though an entotympanic centre may have been present during ossification). Russell[15] has described the extended external auditory meatus and fusion of the tympanic anulus into the lateral wall of the auditory bulla in another skull of *Plesiadapis tricuspidens*; the skull illustrated in Fig. 2 shows these characters even more clearly. An extended external auditory meatus and a tympanic anulus fused into the wall of the bulla characterise all Tarsiiformes but not primates of the infraorder Lemuriformes or

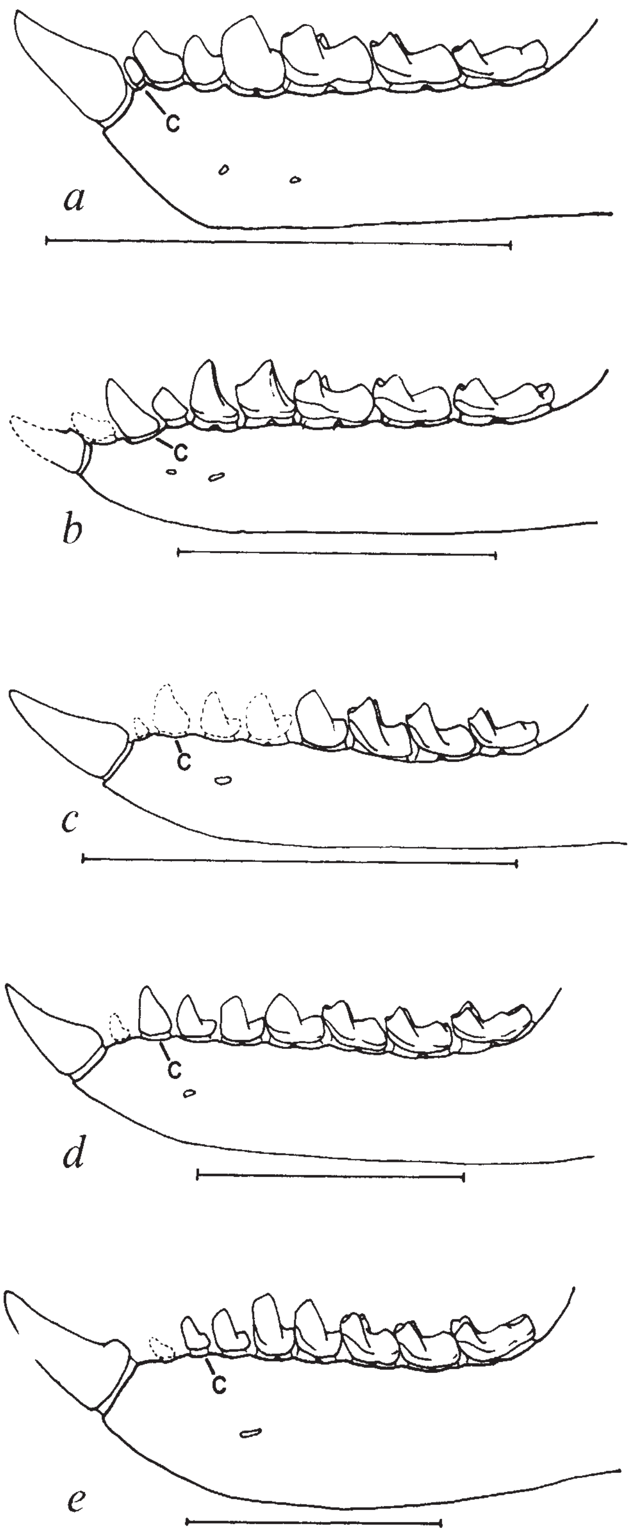

Fig. 1 Comparison of the lower dentition of representative Eocene Tarsiiformes (*Nannopithex* (*a*), *Omomys* (*b*)) with that of middle Paleocene Plesiadapiformes (*Palenochtha* (*c*), *Plesiolestes* (*d*), and the primitive plesiadapid *Pronothodectes* (*e*)). Note enlargement of the central incisor distinguishing these forms from lemuriform and anthropoid primates. *c*, Lower canine. All figures in lateral view and brought to same size for comparison, bar represents 1 cm. Specimens are *a*, Halle IL-8, Geiseltalmuseum in Halle; *b*, AMNH 12600, YPM 13219, 16287, American Museum of Natural History, New York; *c*, PU 14786, 19461; *d*, PU 14149, 17427, Princeton University Museum, New Jersey; *e*, USNM 9332, National Museum of Natural History, Washington, AMNH 35462.

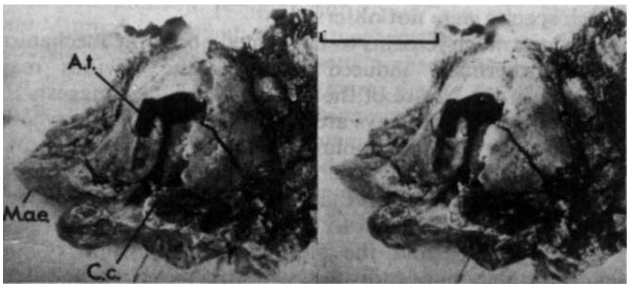

Fig. 2 Right auditory bulla of Pellouin skull of *Plesiadapis tricuspidens* in ventral view (stereophotograph). Note *Necrolemur*-like[12] struts anchoring the tympanic anulus to the lateral wall of the bulla. Fragments were removed from the ventral wall of the bulla to facilitate cleaning. A.t., Anulus tympanicus; C.c., Canalis caroticus; M.a.e., Meatus acusticus externus. This skull of *Plesiadapis* includes an almost complete maxillary dentition, on which its identification is based. Bar represents 1 cm.

primitive Anthropoidea. The ear region of the skull of *Plesiadapis* (and *Phenacolemur*[16]) thus furnishes additional evidence linking plesiadapiform primates to Eocene *Necrolemur*, Oligocene *Rooneyia* and living *Tarsius*, and to the origin of Tarsiiformes.

In both dental conformation and middle ear morphology, generally recognised as the two character complexes of greatest systematic importance among early primates, plesiadapiformes are very similar to early Tarsiiformes and differ greatly from early Lemuriformes. Evidence is presented elsewhere suggesting that Anthropoidea are derived from lemuriform rather than tarsiiform ancestors[17]. Thus there seems, from the fossil evidence, to be a basic dichotomy within the primates separating the infraorders Plesiadapiformes and Tarsiiformes on one hand from the infraorders Lemuriformes and Anthropoidea on the other[10,18]. The earliest lemuroid primates appear abruptly in the fossil record, suggesting that they migrated to Europe and North America at the beginning of the Eocene (as did the earliest rodents and several other important groups). *Purgatorius*, from the Early Palaeocene[19], is the only form known which could possibly be the last common ancestor of all later primates.

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Collective orientation in night-flying insects

SEVERAL investigations have been made using microwave radar techniques to study individual insects in free flight[1-5]. One of the most surprising claims to result from these studies is that insects flying at night sometimes adopt a common orientation, usually downwind[1,2,4]. This would imply a remarkable ability to determine wind direction when flying in conditions of severely limited visibility[1]. We report here an instance of collective insect orientation in nocturnal flight, although in this case, the direction of flight was against the wind.

Our observations were made at Kara in the Niger flood plain in Mali during October, 1973, using radar apparatus modified for entomological observations[5]. The aerial of this radar projects a 'conical' pulsed, microwave beam the axis of which can be set at selected angles of elevation. Rotation of the aerial about a vertical axis causes targets at the appropriate elevations round the radar to be illuminated briefly once per revolution. The resulting radar echoes, if large enough, are registered as 'dots' on a conventional display revolving in synchrony with the aerial. Small targets may be detected at short range and close to the beam axis; larger targets are detectable at greater ranges and further from the axis of the beam. Figure 1 shows typical detection envelopes for two sizes of target. A given airborne volume density of large targets will thus produce more display 'dots' per revolution than the same density of smaller targets.

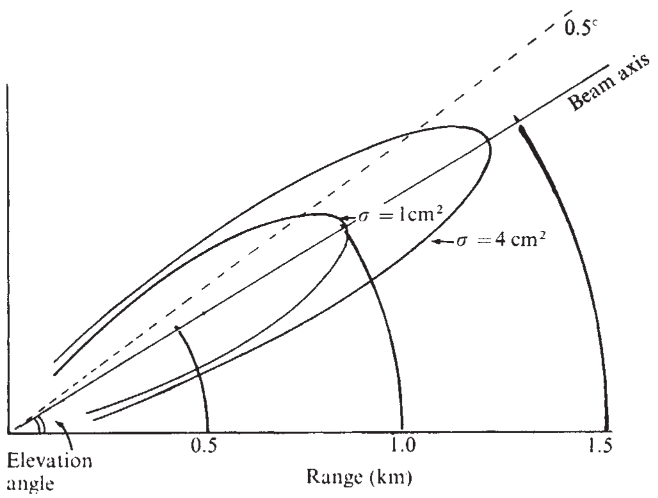

Fig. 1 Typical detection envelopes for two targets of radar cross section (σ) 1 cm² and 4 cm². Targets of these sizes will not be detected outside their respective envelopes. The volume swept out by the envelopes on rotation of the aerial about a vertical axis, and therefore the volumes sampled per revolution for the two sizes of targets, are substantially different. The angular scale in this diagram has been multiplied by 10 to make the effect clear.

Measurements made on captive insects indicate that they generally form substantially larger radar targets when the electric vector in the radar wave has a large component parallel to the insect's major body axis[6,7]. In the case of a radar transmitting horizontally polarised radiation, this means that flying insects will generally present larger 'echoing areas' when flying broadside on to the radar than when end on[2]. A uniform distribution of insects flying with a degree of common orientation in the vicinity of the radar would thus be expected to produce a non-uniform radar display, more 'dots' being seen in the directions from which insects presented predominantly side-on aspects to the radar than in other directions. A pronounced example of this effect is shown in Fig. 2. The distribution of echoes shown in this photograph implies that the insect targets in the vicinity of the radar were predominantly aligned with the 35–215° axis. This 'polarisation' of the echo distribution does not indicate in itself which way along this axis the insects were heading.

Evidence for direction and confirmation of the collective orientation suggested by the polarised display was given by time-lapse photographs of the radar screen. Individual insect echoes were seen to move in the direction of 35° at a ground speed of $\sim 3\ ms^{-1}$ while the radar echo produced by a freely flying balloon (circled), at the same altitude ($\sim$900 m) and carrying strips of aluminium foil, was displaced towards 215° at $\sim 2\ ms^{-1}$. The insect heading in this case was clearly against the wind. The aerial density of insects varied from $\sim$50 per $10^7\ m^3$ at 900 m altitude to 20 per $10^7\ m^3$ at 100 m. The sky was clear with a 7/8 Moon at a bearing of 250°.

The 'polarisation' effect was observed on several nights, being present for 2 or 3% of the observational period (ten nights). The opportunity to provide simultaneous observations