the differentiated mature somatic cells of their origin and were totipotent. These cultures were filtered through graded sieves that passed only cells or cell clusters on the order of 74 μm in size (Fig. 1a), and these units were distributed uniformly throughout a thin layer of agar culture medium which allowed them to grow heterotrophically in darkness (*6*).

It had earlier been shown that such cultures could withstand the simulated physical hazards of lift-off, flight, and recovery (*7*). A low temperature (4°C) was used to minimize biological activity, especially cell division, before launch and after recovery. It was anticipated that once on the spacecraft, where the flight temperature would be 20° to 24°C, metabolic activity, cell division, and growth would resume and morphogenetic potential could be expressed to whatever extent conditions in flight permitted. As controls, dishes comparable to those in flight were maintained at NASA Ames Research Center, Moffett Field, California; at Stony Brook; and in the Soviet Union.

Viable biological material was recovered from the satellite after flight (Fig. 1b). Such data as photographs of the dishes, numbers of developed structures contained in the dishes, and photographs of embryoids at different stages of their development (Fig. 1, a to f) showed that cells flown at 0*g* produced viable embryos in large numbers and that they did not differ significantly from those in dishes at 1*g*.

The particular culture of carrot cells used contained units which, under the conditions of the experiment, varied greatly in the level of the development they achieved. These were classified by size and complexity into several categories and counted (*8*). Representative samples of the different stages of embryogenesis were photographed and examined microscopically. It was possible to establish statistically that the 0*g* and 1*g* treatments did not result in significantly different proportions of embryos at the different stages of development (Table 1). Cellular units, on the order of 74 μm in size (Fig. 1a) and grown for 20 days in darkness, produced embryos at various levels of development (heart, torpedo, early cotyledonary; see Fig. 1, c to f). Embryos that were more advanced had longer roots and better-developed hypocotyls (Fig. 1, b and f). Shoot development, however, tended to be arrested. Nevertheless, the leaf primordia and shoot apices had been initiated and sufficiently established during the flight, at both 0*g* and 1*g*, so that when embryos from the flight were exposed to 1*g* on the earth, their shoots developed rapidly and normally into plantlets (Fig. 1, g to i). Such plantlets subsequently have been raised to maturity.

It is concluded that totipotent somatic cells can undergo morphogenesis to produce fully competent embryos as effectively at 0*g* as at 1*g*. There are, however, two reservations. First, the imposed conditions (total darkness and the duration of the experiment) do not preclude the possibility that the later rapid differentiation of shoots might be more sensitive to 0*g* than the induction of initial embryonic form. Second, it is still possible, although perhaps unlikely, that the cells used in the experiment had retained some consequence of the asymmetric 1*g* stimulus, so that when they did develop at 0*g* in space, they did so with a "memory" of prior or 1*g* conditions. Moreover, only one generation of cells grown to plantlets was studied, and it therefore remains to be seen whether successive generations could be reared in space (*9*).

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4. Each of two experimental canisters contained a stack of nine 50-mm-diameter plastic petri dishes (Falcon No. 1006).
5. Cells were grown in darkness on apparatus similar to that described by F. C. Steward, S. M. Caplin, and F. K. Millar [*Ann. Bot. (London)* **16**, 57 (1952)] in specially designed culture flasks [F. C. Steward and E. M. Shantz, *The Chemistry and Mode of Action of Plant Growth Substances*, R. L. Wain and F. Wightman, Eds. (Butterworth, London, 1956), p. 167] containing 225 ml of White's basal medium supplemented with coconut water (10 percent) and naphthaleneacetic acid (2 mg/liter), and enzymatically digested casein hydrolyzate (0.025 percent).
6. The plating medium consisted of the basal medium of T. Murashige and F. Skoog [*Physiol. Plant.* **15**, 473 (1962)], supplemented with inositol (20 mg/liter) and sucrose (3 percent).
7. J. Tremor, *1975 Joint U.S./U.S.S.R. Biological Satellite Mission: Project Development and Support* (NASA Ames Research Center, Moffett Field, Calif., 1976).
8. The organized forms observed were separated into four sequential stages of embryonic growth as follows: stage 1, heart-shaped forms; stage 2, torpedo-shaped structures, generally less than 0.75 mm long; stage 3, advanced embryonic forms with a distinct root, generally between 0.75 and 1.5 mm long; and stage 4, small plantlets, each with a well-developed root, generally longer than 1.5 mm.
9. This problem has importance for both space biology and "space agriculture" with flowering plants. It is hoped that this question will be submitted to further tests in space.
10. We could take advantage of the opportunity to use Kosmos 782 only because of long prior experimentation to adapt the experimental system to the anticipated conditions of space flight. This was made possible by a series of NASA contracts initially to one of us (F.C.S.) at Cornell University and later to both of us for our collaboration at Stony Brook. All the work before and after the Kosmos 782 flight involved the indispensable help of F. R. Dutcher and E. T. Yim (now Lau). On all matters concerning engineering design, pretesting of the experimental system, and testing of the package as installed in the spacecraft, we worked in close collaboration with staff members at NASA Ames Research Center, especially J. W. Tremor and R. C. Simmonds. After the Kosmos 782 flight plan was initiated, we enjoyed the full cooperation of the appropriate representatives of the Soviet Union, especially in the Institute of Biomedical Problems and the K. A. Timiriazev Institute of Plant Physiology, directed by O. G. Gazenko and A. L. Kursanov, respectively. R. G. Butenko, of the Timiriazev Institute, made available to us the resources of her laboratory and also functioned as our scientifically informed contact in the Soviet Union.

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Orangutan Death and Scavenging by Pigs

Abstract. *Pongid remains are rarely recovered from tropical rain forests. Observations of a Bornean bearded pig* (Sus barbatus) *scavenging an orangutan* (Pongo pygmaeus) *carcass and the recovery of an orangutan skull fragment corroborates evidence from Africa and suggests that the scavenging of wild pigs may play an important role in the destruction of pongid remains.*

Despite recent taphonomic and primatological field studies, there is still a paucity of data on natural death among the great apes and on the fate of their remains. Such data would help in the interpretation of hominoid remains collected from the paleontological record.

Dying pongids apparently retreat under dense vegetation or stay in nests; for this reason they are usually difficult to locate and observe. Aged or ill individuals frequently disappear without any remains being recovered. Both Schaller (*1*) and Fossey (*2*) found mountain gorilla (*Gorilla gorilla beringei*) skeletal remains in the moist montane forests of the Virunga volcanoes, but it was not clear what processes had modified the carcasses after death. Although chimpanzee (*Pan troglodytes schweinfurthii*) deaths from disease, injury, and related causes have been observed at Gombe National Park, chimpanzee carcasses were rarely recovered (*3, 4*). This was attributed to rapid destruction of the remains by scavengers, insects, and microorganisms. In one exceptional case, a chimpanzee corpse was found within a minute or two

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after death caused by a fall from the canopy (*4*). The corpse displayed signs of putrification and maggot infestation after eight hours. The best evidence from Gombe was of baboon remains (*5*). Tracks around partially consumed baboon remains indicated bushpigs (*Potamochoerus porcus*) were probably responsible for the destruction of the carcasses, although scavenging was not directly observed. It is possible that chimpanzee remains at Gombe suffered the same fate.

Until now, no data were available concerning the fate of wild orangutan (*Pongo pygmaeus*) remains. During 5½ years of fieldwork (1971 to 1977) involving 8000 hours of direct observation of an orangutan population in the lowland tropical rain forests of Tanjung Puting Reserve, Central Indonesian Borneo, orangutan remains have been discovered only twice on the forest floor. The first remains consisted of a past-prime adult male who had been characterized by withered cheekpads, emaciated body, and slow locomotion. When discovered on 31 July 1975, this corpse was probably less than 12 hours old as judged from the good condition of the eyes and skin. However, it had already been partially consumed by Bornean bearded pigs (*Sus barbatus*). The face, head, neck, all fingers and toes, and both legs and arms remained intact but the entire contents of the body cavity had been devoured, leaving the vertebral column, scapulae, clavicles, and pelvis exposed. Most ribs were missing. An area of approximately 675 m² around the carcass was covered by pig tracks, small clumps of orangutan hair, and bare patches of earth where the carcass had obviously been repeatedly dragged back and forth along the same route.

One wild pig returned in the presence of the observers. It cautiously moved in (Fig. 1), clamped onto the dead orangutan's shoulder or arm, and began dragging the carcass backward at great speed. This recurred several times and ceased only when the observers moved toward the pig. During the course of the dragging, bones were wrenched out of their sockets and even loosened entirely from the body. One rib was observed detached in this manner while the left humerus was almost ripped free from the skeleton. This dragging dismembered the carcass and rendered the flesh more easily accessible. The pig might have also benefited by avoiding the fire ants which frequently mass on animal remains.

Pigs are generally regarded as omnivorous. Opportunistic predation needs to be considered as the cause of this orangutan's death. Before being shot, a wild pig killed and devoured two domestic ducks and a captive orangutan infant within the confines of our main camp. It is highly unlikely that pigs pose any threat to healthy adult orangutans, male or female. In the one encounter witnessed between a male orangutan walking on the ground and a pig, the ape quickly climbed up an adjacent tree while the pig turned and fled. Nevertheless, the possibility of a wild pig's attacking and killing an aged or ill orangutan on the ground cannot be ruled out.

The remains of the second orangutan, recovered on 1 March 1977, consisted of a skull fragment from an unknown adult male. This fragment seemed totally isolated, since a systematic examination of an area of 10,000 m² around it did not reveal one other scrap of bone. It could well represent the remnant of scavenging by pigs. Only part of the frontal bones, the nasal bone, and a bit of the parietal

Fig. 1. Bornean bearded pig (*Sus barbatus*) approaching orangutan remains (lower left) just before dragging them away. Tanjung Puting Reserve, Central Indonesian Borneo. [National Geographic Society photograph by Rod Brindamour]

remained on the right side; on the left side, part of the maxilla and the zygomatic bone were also present as were two premolars and three molars.

Observations made on a wild pig carcass consumed within a few days by other pigs also indicate the great efficiency of pigs as scavengers and help explain the paucity of animal remains on the forest floor. Thus, without discussing such factors as the extreme acidity of the soil or smaller scavengers (for example, monitor lizards) it becomes clear that the possiblility that anything more than an occasional skull fragment or rib end would survive on this particular tropical rain forest floor for a great enough length of time to be buried and become fossilized seems minimal. Most pongids today still live in tropical rain forests where, presumably, their evolution occurred. Pigs are generally found in these forests. Direct observation of the scavenging of an orangutan carcass in an Asian forest corroborates evidence from Africa and suggests that the scavenging of wild pigs may play an important role in the destruction of pongid remains.

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Bioluminescence: Dual Mechanism in a Planktonic Tunicate Produces Brilliant Surface Display

Abstract. *Luminescent flashes emanate spontaneously and on mechanical stimulation from the bodies of* Oikopleura dioica *(Urochordata, Larvacea); flashes also emanate, on mechanical stimulation only, from both their occupied and discarded mucous houses. The luminescence is intrinsic to the animals and their houses. Field observations suggest that, because of this dual method of light production, larvaceans may contribute substantially to surface coastal displays of marine bioluminescence.*

Brilliant displays of bioluminescence, usually attributed to dinoflagellates, have long been observed in the surface waters of the sea, especially near coasts (*1, 2*). I report here that in some cases larvaceans (Urochordata), and especially *Oikopleura dioica* Fol 1872, contribute significantly to such displays and that the luminescence is produced not only by the organisms themselves but also by the mucous "houses" that they produce (*3*).

The importance of larvaceans in marine planktonic ecosystems has been recognized (*4, 5, 5a*). These organisms are widely distributed and, among zooplankton, their abundances may be second only to, or even exceed, those of copepods, especially in coastal waters (*6–8*). Recent reports of larvacean luminescence (*1, 9*) derive ultimately from a single brief report (*6*) of observations on *O. albicans* (*10*). No reports deal with mechanisms of light production or with field ecology of luminescence in these animals.

Laboratory observations confirmed that both *O. dioica* and its houses luminesce. Freshly collected animals, removed from their houses and transferred to Millipore-filtered seawater, flashed repeatedly with and without mechanical stimulation (Fig. 1, A and B). The flashes, with intensities up to 2×10^9 quanta per second per animal (*11*), emanated from the animals' trunks and had a minimum rise time of 18.0 ± 3.8 msec, a half-decay time of 18.5 ± 4.3 msec, and a total duration of 138 ± 33 msec (mean ± the standard deviation of six flashes) (*12*). Upon mechanical stimulation, discarded houses could be made to flash repeatedly in the absence of the animals, even up to 4 hours after the animals had left them (Fig. 1, C and D). No spontaneous flashes were observed from the houses.

Bacterial, intracellular, and extracellular luminescence has been recognized in metazoans (*1*). Lohmann (*6*) believed that the light in *O. albicans* emanated from a glandular secretion released into the house by the paired buccal glands. The flashes of the animal's trunk are compatible with this explanation, since light could arise from a secretion into the thin layer of mucus comprising the rudimentary house. However, the ability of discarded houses to luminesce repeatedly by means of short flashes and in the absence of the animal suggests membrane-associated sources of light (*13*). Possibilities include (i) luminescent organisms adhering to or living on or in the houses and (ii) *Oikopleura* cells or cell membranes included in the house material itself. Alternatively, a luminous secretion may be sequestered in the house material and reexposed to a necessary factor in the surrounding seawater when the house is mechanically stimulated (*14*).

Bacteria and phytoplankton do occur on and in occupied and discarded larvacean houses (*4, 9*), but there is strong evidence against their being the sources of the light. First, new houses built by *O. dioica* in Millipore-filtered seawater free of these organisms still luminesced in the absence of the animals (*15*). Second, phase-contrast microscopic observations of freshly collected houses did not reveal dinoflagellates on or in the houses. Third, known in situ bacterial luminescence is continuous (*1, 16*). Finally, bacterial luciferase could not be detected in discarded houses (*17*).

Thus, it seems clear that luminescence in both *O. dioica* and its houses is endogenous. That houses can flash apart from the animals suggests mediation of the luminescent response by *Oikopleura* cells or cell membranes left in the houses. The houses of larvaceans are usually assumed to be noncellular (*6, 9*). However, there is evidence (*18*) that small granules ("Häutungskörper"), visible in intricate, species-specific patterns in the rudimentary houses of certain Oikopleuridae, are degenerate cells or nuclei deposited from the animal's trunk epithelium into the house material during its secretion. The significance of these structures is unknown, but it may be that functional cell membranes remain in the expanded house.

Field observations of *O. dioica* suggest that this dual luminescence in larvaceans may contribute significantly to brilliant surface displays of marine bioluminescence. Such displays are usually attributed to high concentrations of dinoflagellates, although often the evidence for their involvement is indirect (*2*). Rarely have the responsible organisms been identified (*2*), and then usually only in specific luminescent bays (*7, 19*) or during conspicuous blooms.

An unusually brilliant display of sur-

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