differences in isozyme patterns are not related to the total phosphatase activity of the preparations, but rather to qualitatively different phosphatase components.

The results of these experiments neither substantiate nor refute the hypothesis of genetic control of leukocyte alkaline phosphatase by chromosome 21. Since, however, the Philadelphia chromosome may persist in acute transformation of chronic granulocytic leukemia while at the same time the leukocyte alkaline phosphatase is elevated, and since the zymogram in the acute disease resembles the normal, the hypothesis of simple genetic control may not be adequate. As Teplitz *et al.* (*10*) have suggested, modifier genes of leukocyte alkaline phosphatase, rather than the structural gene, may be located on chromosome 21.

The results do, nevertheless, help to rationalize the decreased activity of the leukocyte phosphatase in chronic myelogenous leukemia. Apparently the mechanism for controlling the synthesis of the phosphatases is altered to such an extent in the neoplastic cells that decreased amounts, if any, of the usual enzymes are synthesized. Furthermore, those phosphatases which are present in leukemia cells have low activity in the test system. There are, of course, other possible interpretations of the observed difference in the zymogram patterns. For example, the migration rates of the leukemia phosphatases could be the result of alteration of charge on the usual phosphatase components by the action of intracellular degradative enzymes (*11*).

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A Wandering Enteropneust from the Abyssal Pacific, and the Distribution of "Spiral" Tracks on the Sea Floor

Abstract. *Certain coiled tracks appear in photographs from the bottom of most oceans and are abundant in some regions. Enteropneusts are among the forms responsible for such tracks although, despite earlier evidence, they are rarely considered to be either active or abyssal.*

Strange animal burrows and tracks perplex alike the student of deep-sea photographs and the paleontologist; the tracks and burrows may be plentiful enough, but it is often hard to find the animals that made them.

One kind of track, in the form of large coiled or "spiral" patterns (20 to 200 cm in diameter), sometimes appears in photographs of the abyssal sea floor. The patterns begin and end abruptly; we have never discovered traces leading toward their centers or away from their outer ends.

In some places, these tracks are quite plentiful (Fig. 1). On a cruise between Wellington, New Zealand, and Tahiti, the camera recorded them at nearly every station made in depths greater than 4000 m (*Vema*, Cruise 18; *1, 2*). They appeared at 17 of these deep stations but were absent at 69 shallower ones. Later, the U.S.N.S. *Eltanin* photographed them at 60 of more than 200 stations made in the southeast Pacific and the Scotia Sea. Still more "spirals," about 20, have been found in pictures from the North Atlantic, Indian Ocean, and North Pacific. But in our survey they have appeared most often in pictures from the high southern latitudes; the southern South Pacific seems a particularly good place for them (*3*).

At the first of the Pacific stations where the patterns were found (29°40′S, 176°43′W, 4735 m) we photographed very clearly not only the track but the animal responsible (Fig. 2). It is a giant enteropneust, or acorn worm (Hemichordata), about 1 m long, and 5 cm thick just behind the collar. The "spiral" turns out to be the fecal cast, marking the area methodically covered as the animal feeds upon the oozes. If it feeds in the usual way (*4*), particles are trapped in a strand of mucus which is secreted by the proboscis and, by ciliary action, either passed into the mouth or rejected at the collar (our specimen's proboscis is almost hidden at this camera angle). A trace of that mucus, mixed with bits of sediment, can be seen in Fig. 2 to run back from the collar, parallel to the cast.

Hardly anyone mentions enteropneusts as members of the deep-sea fauna. It should be remembered, though, that they are extremely fragile animals and unlikely to survive a trawling, so that their absence from collections (like the absence of the big squids) must be, sometimes at least, the fault of the fishing methods. Our pictures show tracks concentrated in places where comparatively little trawling has been done.

But it would be quite wrong to take the distribution of the tracks as the distribution of abyssal acorn worms. Those few pictures which show animals as well as tracks have, regrettably, been too unclear for sure identification. Possible records come from the North Atlantic, the New Hebrides Trench, the Peru-Chile Trench, and the Bellinghausen Sea, but the North Atlantic record is particularly doubtful. One photograph from the Pacific, however (Fig. 3), does show the same sort of track as the enteropneust's, but it was made by a distinctly different animal. Perhaps it was an echiuroid worm; a number of abyssal echiuroids have been collected in the Pacific by the *Vityaz* (*5*).

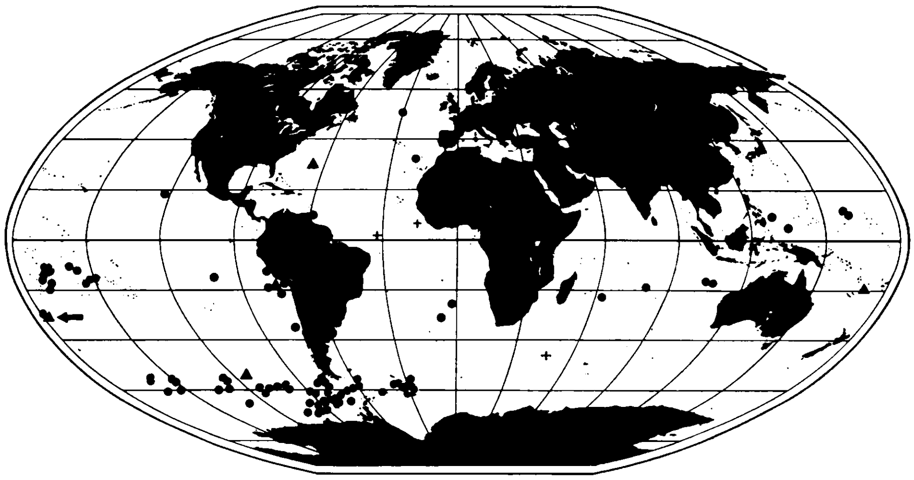

Fig. 1. Spiral tracks photographed on the abyssal floor. Symbols: ●, spirals; ▲, animals associated with spirals; ←, wandering abyssal enteropneust; +, dredged abyssal enteropneusts.

Fig. 2. An abyssal acorn worm from the wall of the Kermadec Trench. The animal's body ends shortly past the first bend, and the fecal cast begins. A similar cast is seen at the left of the picture, and a portion of another type, with a median furrow, is at the top. The photograph was made with a Thorndike camera (triggered by contact with the bottom) and the area shown here is about 5 m^2.

Still other tracks ("pasichnia"), left by a variety of animals and in pattern strikingly like those in our photographs, have been found fossilized (Fig. 4; *6*). But then we might expect the pattern to be common, since it is an efficient way to cover all the ground and none of it twice.

To find an enteropneust that makes any sort of track is remarkable, for they are generally thought only to live protected in burrows or, for example, among rocks or the holdfasts of seaweeds. In the most recent work on their physiology (*4*), Barrington concludes that they are ill equipped by their cilia and feeble musculature for free locomotion. He speaks of some fishermen's accounts of acorn worms lying about on the mud, but he does not credit them. Nor does he mention the independent accounts by Ikeda and Spengel (*7*, *8*; see also *9*) of *Glandiceps* swarming at the surface of the water.

The case that Spengel describes was reported to him by the ship's doctor and other officers of the *Siboga*, who found great numbers of *G. malayana* swimming at Surabaya. Ikeda himself saw the phenomenon three times while collecting with his students in the Seto Naikai. Because it is so little known, his description deserves quoting:

"A little later, when the sun was about to rise, we could perceive myriads of lively swimming specimens about our boat. We now came to realize that we had been rowing about in a big sheet of swarming Enteropneusts. . . . The belt-like zones of this plankton varied from one to five metres in width, and were in some cases two metres in thickness. . . . After nearly a hundred yards' row, we came across another broader sheet of swimming Balanoglossus. There they were so thick that we could count nearly a hundred specimens in a cubic foot of water. When the sun was up, this curious plankton almost suddenly disappeared."

Ikeda goes on to observe that the species he saw, *G. hacksii*, is flattened at the tail, and markedly darker on its dorsal surface than on its belly; it is a "creeper" as well as a swimmer. The swarming animals, he says, were feeding upon diatoms and dinoflagellates, and their guts were packed with them.

Barrington (*4*) claims "general agree-

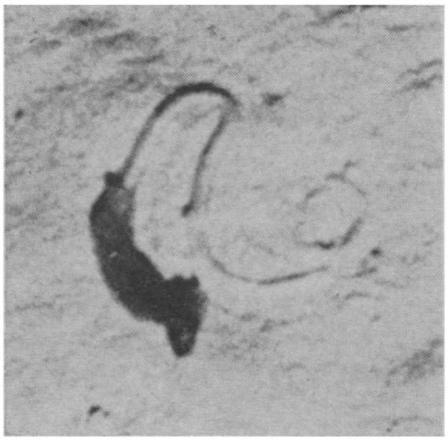

Fig. 3. A second trackmaker, perhaps an echiuroid worm, taken at 3480 m in the southeast Pacific (54°55′S, 114°44′W).

ment" that enteropneusts "rarely, if ever, move completely out of their burrows," and he feels that "their behaviour is only to be understood in relation to their burrowing habit." Clearly, this is a view to reconsider.

We do not know, of course, whether the animal in our picture (Fig. 2) burrows some of the time. It would be surprising if it did not, for there are plenty of compromises to be found between a sedentary and an active life (larval lampreys are one example), where a disposition toward one habit does not preclude the other. When sedentary acorn worms are placed out on the surface, they manage a slow progress (*9*) and this may be sufficient for abyssal circumstances. Conclusions based on shallow-living specimens, that is to say, may have more to do with habit than with capacity.

So far as we can discover, our photograph (Fig. 2) is the first abyssal record for an enteropneust since 1873, when the *Challenger* dredged three damaged "Balanoglossus" (*10*). The first of these was taken (in about the same depth as our picture) off West Africa (5°48′N, 14°20′W, 4545 m) and was described and figured years later by Spengel as *Glandiceps abyssicola* (*11*). The sketch and field notes from the *Challenger Report* give some idea of the fresh specimen's appearance. It was, these notes say, "probably of considerable length" and "distinguished by very lively colours" (Fig. 5). The remaining specimens taken were too damaged for description, but there seems little doubt that they were enteropneusts. One was taken in the mid-Atlantic, near St. Paul's Rocks, and the other in the southern Indian Ocean, between the Marion Islands and the Crozets, at 3360 m and 2910 m, respectively. (Apart from the tracks, which are problematical, the latter record and an endemic New Zealand species represent the known southerly limit for the Enteropneusta.)

Two other enteropneusts have been reported from moderate depths: *G. talaboti,* from 30 to 350 m in the Mediterranean, and *Spengelia sibogae,* from 275 m in the Sulu Sea (*9*). Both genera are in the family Spengelidae.

Detailed identification from photographs is difficult, as a rule, and especially so when the group is as little known as the enteropneusts. But our specimen has conspicuous genital wings (forming the margins of the slit visible in the animal's back) which distinguish it at once from *G. abyssicola* and other known spengelids. Genital wings are particularly characteristic of the family Ptychoderidae, yet, if this specimen were a ptychoderid, hepatic sacculations, a second feature of that family, should be quite obvious as well. They are not; the animal's body, though slightly darkened, is perfectly smooth in the hepatic region.

But genital structures can vary considerably within families, and this specimen, despite its having wings like a ptychoderid's, is more likely a spengelid or a harrimaniid. The Spengelidae, considered the intermediate family in the classification (*9*), have already shown some capacity for deep-water life as well as active habits. The Harrimaniidae, on the other hand, include all of the truly cold-water species described (excepting *G. abyssicola*). The lecithotrophic type of development (yolky eggs giving rise directly, or nearly so, to the young worms) has been demonstrated in some of them (*4, 9*) and this is worth noting, for it is an adaptation shared with nearly all benthic invertebrates, and a number of fishes, from the arctic and from the deep sea (*12*).

Ptychoderids, conversely, are found in tropical and temperate waters, and are reported generally to have a planktonic (tornaria) stage in their development. Not all tornariae are found in the surface layers (tornariae of *G. talaboti* have been taken at 100 m) (*9*) but their depth range must be limited by the plankton on which they feed. Perhaps some of the Ptychoderidae develop directly, but, on the evidence,

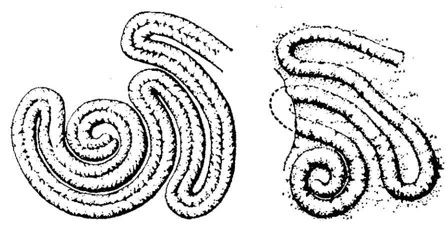

Fig. 4. Fossil tracks (*Taphrhelminthopsis,* left, and *"Mülleria"*) from the Alpine flysch, thought to be abyssal in origin [from Seilacher (*6*)].

they appear the least likely of enteropneust families to have colonized abyssal depths.

For such naked and fragile animals as acorn worms to survive exposed, we should expect their habitat to be free of much current and of large predators. In some areas where the tracks were photographed, the southwest Pacific for instance, the sea floor seems almost barren of other life. However, at the three stations where the *Challenger* dredged enteropneusts, a variety of animals were taken, sometimes plentifully (*10*). The only fish caught was a macrourid (a type unlikely to threaten larger enteropneusts), and among the invertebrates were both sedentary and active forms. In fact, most of the groups commonly found at such depths were represented, including detritus browsers such as ophiurans, holothurians, and urchins. Nothing in the station lists, except the "Balanoglossids" themselves, seems to distinguish these localities from hundreds of others where no enteropneusts were found.

Based on the *Challenger's* evidence and our own, the Enteropneusta occur at abyssal depths in three oceans: the

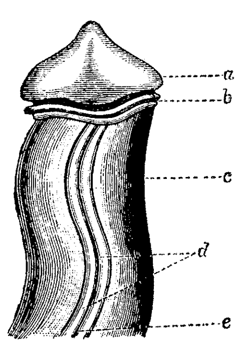

Fig. 5. *Glandiceps abyssicola* Spengel, natural size, from a sketch by von Willemoes-Suhm. The proboscis, *a*, was yellow; the collar, *b*, bright red; and the trunk, *c*, yellowish-red; *d* and *e* designate the mid-dorsal ridge and blood vessel. [*Challenger Reports* (*10*)]

Atlantic, Indian, and southwest Pacific. The tracks probably (but not certainly) show a wider distribution, as we have described, and suggest that these animals, in some regions, may be quite common.

It would be interesting to know how, in these places, acorn worms divide the spoils with other detritus feeders. We might also ask why, in an environment suitable for so many sedentary forms, they are free living. Conceivably, like the *Glandiceps* Ikeda (*7*) saw, some of these abyssal worms can swim, and choose good feeding grounds. Perhaps, though, the explanation is simply negative; that is, that for them, burrowing in this habitat is seldom necessary (*13*).

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13. After this paper was completed, F. Jensenius Madsen of the University Museum, Copenhagen, showed one of us (D.W.B.) a number of photographs made by the Scripps Institution of Oceanography in the southwestern Pacific. Spiral tracks are plentiful in some of them, and in one case an animal resembling an enteropneust has been photographed together with its spiral.
14. Lamont Geological Observatory, Columbia University, Contribution No. 841. Woods Hole Oceanographic Institution Contribution No. 1639. We thank Dr. Sydney Smith, University of Cambridge, for his criticisms and advice. Rockne Anderson and Charles Hollister, Lamont Geological Observatory, provided valuable assistance. Work supported in part by NSF grant G-20702 to the Woods Hole Oceanographic Institution, under contract Nonr 266(48) with Columbia University, and by the ONR.

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Spectrum of the Intensity Variations in 3C 273B

Abstract. *The intensity variations in radio source 3C 273B have been measured at wavelengths of 31.3, 21.2, and 10.6 centimeters. At 31.3 centimeters the variation is quite small, indicating that the variable component of the source is optically thick at this wavelength. Study of several different model sources shows that the observed dependence of the intensity variations on frequency can best be explained by an increase of the electron density in a source region about 2 parsecs in diameter. This interpretation is consistent with the distance to 3C 273 determined from Hubble's law and the observed red shift.*

Dent (*1*) has observed an increase of 17 percent per year in the intensity of the radio source 3C 273B at a wavelength of 3.75 cm. His interpretation of this intensity variation brings into question either (i) the production of the radiation by the synchrotron mechansm or (ii) the distance of about 470 megaparsecs determined from Hubble's law and the observed red shift (*2*) of $\Delta \lambda / \lambda = 0.158$.

We have observed changes in the intensity of 3C 273B at wavelengths of 31.3, 21.2, and 10.6 cm, as shown in Fig. 1. The measurements plotted in Fig. 1 come from several observers, as indicated in the legend. All but two (*3, 4*) were taken with the interferometer at the Owens Valley Radio Observatory. The Owens Valley observations were all made with a linearly polarized antenna feed in which the electric vector pointed north-south. Also shown in Fig. 1 is a line representing the intensity increase at 3.75 cm reported by Dent (*1*). Dent gave intensity ratios to the source Virgo A. These have been converted to fluxes; a value of 45 flux units for Virgo A at 3.75 cm was used (*1*).

A straight line has been fitted to the data for each wavelength. There is some indication in the data for 21.2 cm that the rate of increase was less between 1960 and 1963 than it has been in the subsequent period; however, the individual points have fairly large uncertainties and the straight line provides an adequate fit.

The spectrum of the intensity changes is shown in Fig. 2. There is a sharp cutoff between 20 and 30 cm, with a gradual increase in the rate of change as the wavelength decreases from 20 to 3.75 cm. The sharp long-wavelength cutoff suggests strongly that the intensity changes are occurring in a component of the source which is optically thick at wavelengths greater than 20 cm.

If the time scale of the intensity variations is set by the dimensions of the variable component, we can say that the component diameter is about 2 parsecs. At the cosmological distance of 3C 273, this would correspond to an angular diameter of about 0.001 second of arc. Using the synchrotron emission and absorption coefficients given by LeRoux (*5*), we find that an object subtending 0.001 second and having an apparent flux of 10 to 20×10^{-26} watt m^{-2} $(cy/sec)^{-1}$ would become optically thick at some wavelength between 3 and 30 cm. The exact value depends slightly on the strength of the magnetic field and the energy spectrum of the relativistic electrons.

Thus the observed intensity variations in 3C 273B are *not* in conflict

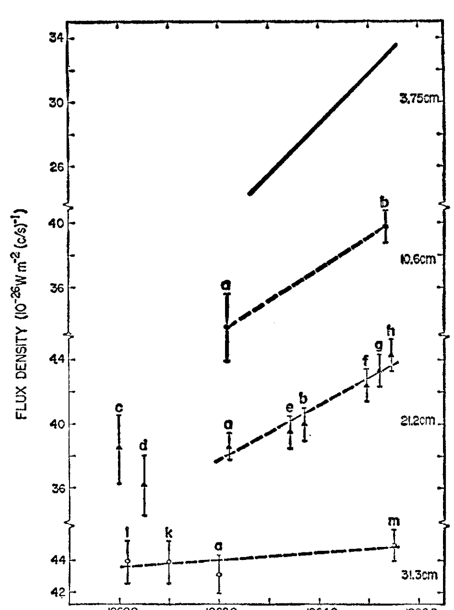

Fig. 1. Measured intensities of 3C 273 versus time at 31.3, 21.2, and 10.6 cm. For comparison, the intensity variation measured by Dent (*1*) at 3.75 cm is shown (top). The various observations were made by (*a*) Kellermann (*8*); (*b*) Moffet; (*c*) Lequeux (*3*); (*d*) Goldstein (*4*); (*e*) Morris; (*f*) Fomalont, Rogstad, and Wyndham; (*g*) Fomalont; (*h*) Rogstad and Whiteoak; (*i*) Moffet (*9*); (*k*) Maltby (*10*); (*m*) Maltby and Moffet.