of the fact that the only particles known at present have a nucleonic charge of 0 or ±1; and why should the decay of the universon into particles of large nucleonic charge be a preferred mode?

It remains to be seen whether these speculations, which are most easily visualized in a Newtonian universe, can be formulated in a way that is compatible with the ideas of the general theory of relativity.

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2. I should like to thank R. Schlegel for useful comments.
3. In a sufficiently dense environment, the total energy released in the mutual annihilation of electrons and positrons (1 Mev in the form of γ-rays) may be transformed into heat; up to about one-half the energy released in the mutual annihilation of nucleons and antinucleons (1876 Mev in the form of π-mesons, charged and uncharged) may be transformed into heat, the remainder being carried away by neutrinos, resulting from decay of the charged mesons. The decay modes of the π mesons are $\pi^{\circ} \rightarrow 2\gamma$; $\pi^{\pm} \rightarrow \mu^{\pm} + \nu$; $\mu^{\pm} \rightarrow e^{\pm} + 2\nu$.
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8. Gamow (see *4*) suggests that one may escape discussion of the creation of the "ylem" or "polyneutron" if the "beginning," $\backsim 4.5 \times 10^9$ years ago, was only the latest beginning of an expansion of the universe which may ultimately be followed by a contraction and a new expansion, in endless cycles.
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26 April 1956

Mechanism of Sound Production in the Sculpin

Definite information on the sound-producing mechanisms of many fishes has been obtained, especially on those of species possessing swimbladders and associated intrinsic or extrinsic muscles (*1, 2*). In many other species, including either those without swimbladder muscles or those entirely without swimbladders, this mechanism is less fully understood. For example, in marine sculpins, which are fishes lacking swimbladders, Fish (*2*) suggests a possible mechanism in *Myoxocephalus octodecimspinosus* Mitchill which involves pectoral-pelvic girdle vibration, and she describes two other mechanisms proposed by earlier investigators (*1, 3*).

In the experiments reported here (*4*), muscles considered to be primarily involved in sound production in the longhorn sculpin, *M. octodecimspinosus,* have been identified by use of electrophysiological techniques. These experiments suggest that a different mechanism is involved. Muscle-action potentials that were coincident with each burst of sound were detected by a cotton-wick electrode and a capacitor-coupled preamplifier that provided a gain of 44 db. The output was aurally monitored by a separate audio amplifier-loudspeaker circuit, displayed on a 5-in. oscilloscope, and recorded on magnetic tape by a Magnecord PT63 at 7.5 in./sec for detailed analysis and photorecording.

The action-potential pulses could be picked up from all parts of the body surface, increasing in amplitude in the vicinity of the gill chamber. The point of maximum amplitude (2 to 3 mv) was the posterior, dorso-lateral corner of the gill chamber on each side of the body near the junction of the posterior edge of the operculum with the dorsal body wall.

Careful dissection revealed the presence in that location of two muscles, one superficial to the other. Both muscles insert on the anterior edge of the cleithrum near the point of articulation of the latter bone with the supraclavicle. Both have their origin from the ventral surface of the skull, the deep muscle from the posterior region of the otic capsule just lateral to the midline and the superficial muscle from a more lateral region. Their contraction would thus produce adduction of the pectoral girdle relative to the skull. The homology of these muscles has not been determined with certainty. In some respects, they resemble either cephaloclavicularis or cucullaris muscles, but the deep muscle, at least, is innervated by branches of the first two spinal nerves rather than the vagus (*5*).

Electrophysiological recording directly from the surface of the exposed muscles indicated the deep muscle to be the source of the action potentials. That it is the only source is indicated by the fact that the superficial muscle could be completely removed without altering the nature of the spikes, and no other muscle site was found to yield such action potentials.

The relationship between the action potentials and the sound-producing vibrations was determined by comparing both separate and simultaneous oscillographic records of the two phenomena. The vibrations were detected by a crystal phonograph cartridge holding a stiff wire which rested near the coracoid

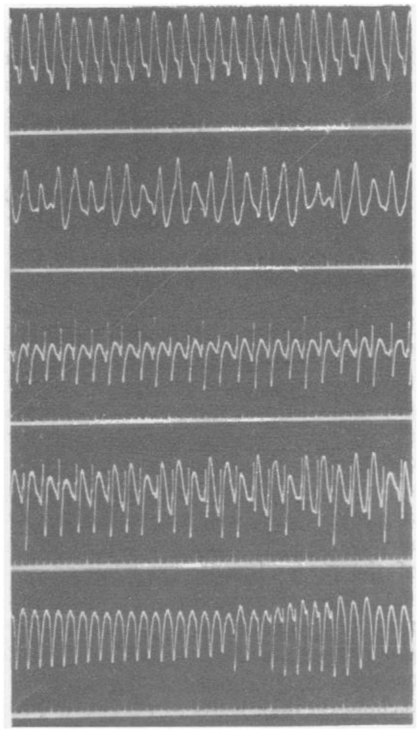

Fig. 1. Mechanical and electric events occurring during sonic activity in the longhorn sculpin. The top four records are from the same animal. Top to bottom: underwater sounds, pectoral-girdle vibrations, action potentials, simultaneous action-potential and pectoral-girdle vibrations, contractions of the deep cephaloclavicularis muscle. Time marks occur every 10, 50, and 100 msec.

symphysis, where maximum vibration could be felt. The crystal output was connected directly to the oscilloscope input. For simultaneous recording, the two potentials were first combined in a two-channel audio mixer that had separate volume controls for amplitude equalization. Contractions of the deep muscle from one side of the body were recorded separately during sound production by tying the severed insertion of the muscle to the crystal pickup.

The following facts are evident from examination of the oscillograms. Typical examples are shown in Fig. 1. (i) Except for minor differences in records made at different times, the repetition frequencies of the muscle-action potentials, underwater sounds recorded by hydrophone, and pectoral-girdle vibrations are identical. (ii) The pectoral-girdle vibrations occur in phase with the muscle-action potentials. (iii) The deep-muscle contractions during sound production consist of a series of separate twitches, of which the repetition rate is similar to that of the phenomena reported here. The frequency difference that is visible in Fig. 1 between the bottom record and the preceding ones is apparently an individual variation.

Therefore, it is concluded that the

sound-producing mechanism of the longhorn sculpin is actuated by contractions of the deep cranioclavicular muscles on both sides. The resulting periodic movements of the pectoral girdle are believed to produce the actual sound vibrations of the surrounding medium. The previously suggested source of the vibrations, pectoral-pelvic girdle stridulation (*2*), was disproved by amputating the pelvic girdle, without injury to the pectoral girdle, in three specimens. For more than 24 hours after the operation, all three fish readily produced apparently normal sounds. In the absence of antagonistic muscles for the production of a reciprocating movement, it is suggested that the deep muscles produce unidirectional movement and that the return movement is produced by the elastic nature of the pectoral-girdle articulations.

Further analysis of the sculpin sound-producing mechanism is in progress. The preliminary results from this species suggest that analogous electrophysiological techniques may assist in providing positive identification of unknown-sound-making structures in other species.

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21 May 1956

Some Effects of Specific Organic Compounds on Marine Organisms

In recent years it has become increasingly recognized that sea water contains organic compounds in solution or suspension which may have definite roles in the living processes of marine organisms (*1–3*). Thus it is reasonable to expect that a number of vitamins that may affect the bioeconomy of the sea are produced naturally (*4*).

This report describes two cases of interest which have come from our studies of the organic components of sea water. These results are considered to be significant because the presence of one of the compounds has been demonstrated by chemical methods (*2*) and because the other could easily be presumed to be present. In addition, both components showed definite physiological effects on the animals used.

Table 1. Effect of niacinamide on the pumping rate of an individual oyster.

Niacinamide (ppm)	Reduction in pumping rate (%)
0.42	52
0.83	83
2.08	99
3.33	99
10.00	100
50.00	100

During the experimental work of Collier *et al.*, various organic compounds were introduced into the water supply of experimental oysters [*Crassostrea virginica* (Gmelin)] in an attempt to obtain a response similar to that caused by the natural carbohydratelike substances (*5*). Niacinamide was among these, and although it did not cause an increase in pumping rate, its effect was pronounced and quantitative in nature. The effect was easily repeated from oyster to oyster under a variety of conditions. Briefly, the maximum effect was to cause an immediate increase in the gape (openness of the valves) of the oyster and, simultaneously, a complete cessation of pumping. The niacinamide was introduced into the water-circulating system in various concentrations. Table 1 summarizes the results of a series of experiments on a single oyster. The shell movement is difficult to quantitate, but, as the pumping rate decreased, the gape of the oyster gradually increased and, simultaneously, the adductor muscle lost tonus.

These data are typical, and it can be seen that the pumping rate was inversely related to the concentration of niacinamide. Some points to be noted are (i) that the substance was not acting as an irritant in the normal sense, because an irritant normally causes an oyster to snap shut or show frenetic shell movements, as compared with the quasi-narcosis in this case; (ii) that the valves could be pressed to the closed position but would immediately return to full gape; (iii) that the maximum gape caused by the niacinamide was actually about 10 percent greater than that associated with normal maximum pumping; (iv) that, as the niacinamide was gradually removed by dilution with normal, running sea water, the activity of the oyster resumed the level prevailing before the introduction of the vitamin; and (v) that niacin caused no response in similar concentrations.

Our work on the natural organic compounds in sea water is continuing and further tests with specific organic compounds are under way.

Of a series of compounds used with barnacles, ascorbic acid caused the most clear-cut response. When the barnacles (*Balanus* sp.) were exposed to a maximum concentration of 0.014 mg of ascorbic acid per liter, they immediately initiated copulating activities. The cirri ceased beating, and the penis emerged, unrolled, and sought out nearby barnacles. The ascorbic acid was introduced at one point, and because it was carried through the remainder of the 25-gal tank by convection drifts, all of the barnacles responded in the same manner. This would indicate that they were sensitive to much less than the original concentration. The experiment could be repeated at will with the same results, and changes in *p*H that were caused by adding HCl in place of ascorbic acid did not stimulate the response. The barnacles were fully grown animals that had been reared from larvae in the aquarium where the experiments were performed. These tests were made when the barnacles were 38 days old.

For comparison, glutamate, glycogen, methionine, and inositol were also used and seemed to stimulate a more rapid beat of the cirri. Fish autolysate appeared to depress the rate. None of these caused the responses noted for ascorbic acid.

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Detection of Tumor-Inducing Factors in Drosophila

Many investigations have been concerned with the occurrence of melanotic tumors in *Drosophila melanogaster*. The effects of environmental modifications—that is, nutrition (*1*), temperature (*2*), and x-radiation (*3*)—on tumor incidence in various strains have been extensively studied. Melanotic tumors have been