ent during the time when the present magnetization was acquired. Apparently, the best procedure is to continue to accumulate field evidence.

It was possible (*2*) last summer to make a survey of the remanent magnetization of some of the lava flows of the San Francisco Mountain, Verde Valley, and Mormon Mountain volcanic fields in northern Arizona. It was thought sufficient to determine the polarity rather than the exact direction of magnetization of the specimens. For this it is possible in the majority of cases to use a Brunton compass. Assuming that the specimen is magnetized normally or reversely, the poles of the specimen are brought near the poles of the compass, and repulsion or attraction is noted. Increased sensitivity can be obtained by moving a pole of the specimen from side to side over one end of the compass needle and noting whether the needle moves in phase or antiphase with the specimen.

Occasionally, a few specimens in a single flow were found to be magnetized differently from the rest, but, as these specimens were usually very intensely magnetized and had been collected from exposed points, it was assumed that lightning strokes were responsible.

From the extent of the erosion of the lava tops and fronts, Colton (*3*) has arranged the lavas of the San Francisco volcanic field in order of age, stage I being the oldest, stage V the youngest. Sharp (*4*) considers stage III lavas to be younger than about 60,000 years and stage II lavas probably older. Robinson (*5*) considers the earliest flows in this region to be Pliocene. Work done by Childs (*6*) on pediplane surfaces of the Colorado plateau shows that the stage I flows rest on a late Pliocene surface and that the stage II flows occurred before the first glaciation in the San Francisco peaks, probably in the early Pleistocene.

Nine stage III flows, one stage IV, and one stage V flow were examined and found to be normally magnetized. This is in accord with the evidence from the New England varved clays which cover a fair proportion of this time. The data from Iceland and France would indicate that stage II covers the Pliocene-Pleistocene boundary. One out of six lavas examined in the Verde Valley volcanic field was reversely magnetized, and 13 out of 21 in the Mormon Lake volcanic field were reversely magnetized.

All these flows were of stage I or II. In these fields, one normally magnetized lava and two reversely magnetized flows have been found overlying baked clay horizons. The latter were found to be magnetized concordantly with the respective lavas. The clay was thus heated by the lava and, on cooling, acquired a magnetization in the same direction as the lava. If the second hypothesis were true, this would not always occur.

The results that very recent flows are always found to be normally magnetized and baked clays have the same magnetization as the lava which bakes them are in accord with evidence from other lava series. It must be concluded that this evidence from northern Arizona lends support to the first hypothesis. If this hypothesis is correct, the earlier flows in this region must be at least about 1 million years old (*7*).

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1 February 1956

Ecosystem as the Basic Unit in Ecology

The term *ecosystem* was proposed by Tansley (*1*) as a name for the interaction system comprising living things together with their nonliving habitat. Tansley regarded the ecosystem as including "not only the organism-complex, but also the whole complex of physical factors forming what we call the environment." He thus applied the term specifically to that level of biological organization represented by such units as the community and the biome. I here suggest that it is logically appropriate and desirable to extend the application of the concept and the term to include organization levels other than that of the community.

In its fundamental aspects, an ecosystem involves the circulation, transformation, and accumulation of energy and matter through the medium of living things and their activities. Photosynthesis, decomposition, herbivory, predation, parasitism, and other symbiotic activities are among the principal biological processes responsible for the transport and storage of materials and energy, and the interactions of the organisms engaged in these activities provide the pathways of distribution. The food-chain is an example of such a pathway. In the nonliving part of the ecosystem, circulation of energy and matter is completed by such physical processes as evaporation and precipitation, erosion and deposition. The ecologist, then, is primarily concerned with the quantities of matter and energy that pass through a given ecosystem and with the rates at which they do so. Of almost equal importance, however, are the kinds of organisms that are present in any particular ecosystem and the roles that they occupy in its structure and organization. Thus, both quantitative and qualitative aspects need to be considered in the description and comparison of ecosystems.

Ecosystems are further characterized by a multiplicity of regulatory mechanisms, which, in limiting the numbers of organisms present and in influencing their physiology and behavior, control the quantities and rates of movement of both matter and energy. Processes of growth and reproduction, agencies of mortality (physical as well as biological), patterns of immigration and emigration, and habits of adaptive significance are among the more important groups of regulatory mechanisms. In the absence of such mechanisms, no ecosystem could continue to persist and maintain its identity.

The assemblage of plants and animals visualized by Tansley as an integral part of the ecosystem usually consists of numerous species, each represented by a population of individual organisms. However, each population can be regarded as an entity in its own right, interacting with its environment (which may include other organisms as well as physical features of the habitat) to form a system of lower rank that likewise involves the distribution of matter and energy. In turn, each individual animal or plant, together with its particular microenvironment, constitutes a system of still lower rank. Or we may wish to take a world view of life and look upon the biosphere with its total environment as a gigantic ecosystem. Regardless of the level on which life is examined, the ecosystem concept can appropriately be applied. The ecosystem thus stands as a basic unit of ecology, a unit that is as important to this field of natural science as the species is to taxonomy and systematics. In any given case, the particular level on which the ecosystem is being studied can be specified with a qualifying adjective—for example, community ecosystem, population ecosystem, and so forth.

All ranks of ecosystems are open systems, not closed ones. Energy and matter continually escape from them in the course of the processes of life, and they must be replaced if the system is to continue to function. The pathways of loss and replacement of matter and energy frequently connect one ecosystem with another, and therefore it is often difficult to determine the limits of a given ecosystem. This has led some ecologists to reject the ecosystem concept as unrealistic and of little use in description or analysis. One is reminded, however, of the fact that it is also difficult, if not impossible, to delimit a species from its ancestral or derivative species or from both; yet this does not destroy the value of the concept. The ecosystem concept may indeed be more useful when it is employed in relation to the community than to the population or individual, for its limits may be more easily determined on that level. Nevertheless, its application to all levels seems fully justified.

The concept of the ecosystem has been described under many names, among them those of *microcosm* (*2*), *naturkomplex* (*3*), *holocoen* (*4*) and *biosystem* (*5*). Tansley's term seems most successfully to convey its meaning and has in fact been accepted by a large number of present-day ecologists. I hope that it will eventually be adopted universally and that its application will be expanded beyond its original use to include other levels of biological organization. Recognition of the ecosystem as the basic unit in ecology would be helpful in focussing attention upon the truly fundamental aspects of this rapidly developing science.

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Hypothermia by Internal Cooling

Mammals normally maintain their body temperatures at a constant and relatively high level. Chemical and other body reactions speed up with increase in temperature and slow down at lower temperatures. Chemical-reaction rates approximately double for each 20-deg rise in temperature.

In surgery it is desirable to slow down body reactions to allow more time for certain operations (*1, 2*). Hypothermia has been used with some success in such work, but the cooling methods that were used introduced several problems, such as ventricular fibrillation, the necessity of prolonged preoperative preparation of the patient, and, most important of all, the biological catastrophe of overreaction of the organism to the stress of the shock of surface cold application (*3*). Cooling the body from the outside requires a long time to extract the body heat through the outer layers of fat and muscular natural insulation (*1, 4*). It seemed to us that a more rapid lowering of the body temperature could be accomplished by internal cooling through the lowering of the temperature of the animal's circulating blood in an external heat exchanger. The cooled blood returning to the body would act as a heat-absorbing and transferring medium to reduce rapidly the body temperature.

Table 1. Temperatures for 11 dogs during hypothermia experiments.

DOG NO.	INITIAL RECTAL TEMP.	MAXIMUM HYPOTHERMAL RECTAL TEMP.	TEMP. CAROTID ARTERY LIMB		TEMP. FEMORAL VEIN LIMB		TEMP. AFTER REWARMING	CONDITION OF DOG
			INITIAL	REWARM	INITIAL	REWARM		
1	100°	80°	78°	72°	72°	79°	96°	FULL RECOVERY
2	102°	80°	86°	80°	71°	86°	94°	
3	104°	85°	37.6°	81°	76°	82°	92°	"
4	100°	82°	87°	84°	67°	84°	94°	"
5	102°	86°	92°	80°	72°	86°	80°	"
6	103°	76°	82°	75°	73°	85°	90°	"
7	100°	78°	85°	76°	76°	84°	88°	"
8	100°	79°	81°	76°	66°	77°	96°	"
9	104°	76°	84°	78°	68°	80°	92°	"
10	100°	80°	78°	82°	66°	78°	88°	"
11	102°	80°	76°	74°	66°	78°	90°	"

To accomplish this, the following procedure is used. After minimal anesthesia with intravenous Nembutal and with tracheal intubation, the animal is connected to a respirator. The carotid artery is cannulated with a polyethylene tube that is threaded through a circulating pump and is then coiled around a spindle that is immersed in a refrigerated alcohol-water bath. The return end of the polyethylene tube is then inserted in the femoral vein.

In a series of 30 dogs, very good results have been obtained. A dog is cooled from 100°F to 80°F in 20 minutes. No cardiac fibrillation, shivering, or shock manifestations are encountered during the procedure. Several animals have been cooled to a complete cardiac standstill and then returned to normal rate and rhythm by rewarming (Fig. 1). It is necessary only to bring the dog up to 90°F, which is above the shivering point. The animal recovers to normal by itself after this.

Rewarming is accomplished by the use of a heating unit in the cooling bath. The refrigeration is shut off, and the heating unit is activated to warm gradually the bath, which in turn warms the circulating blood of the animal (Table 1).

By this method of producing hypothermia by internal heat exchange, the blood and body temperatures may be

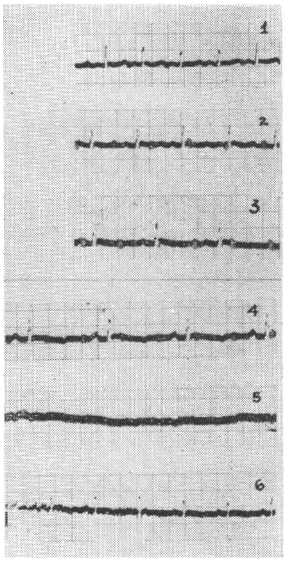

Fig. 1. Cardiographs of dog: (1) normal sinus rhythm, prehypothermia; (2, 3, 4) increasing R-R internal and prophasive delay in repolarization of myocardium, shown by markedly prolonged electric systole, (5) apparent cardiac asystole; (6) sinus rhythm, early posthypothermia.

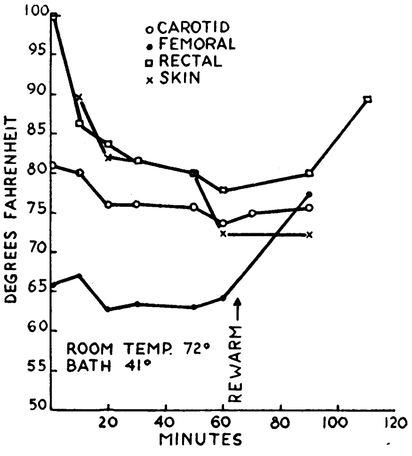

Fig. 2. Related temperatures during hypothermia.