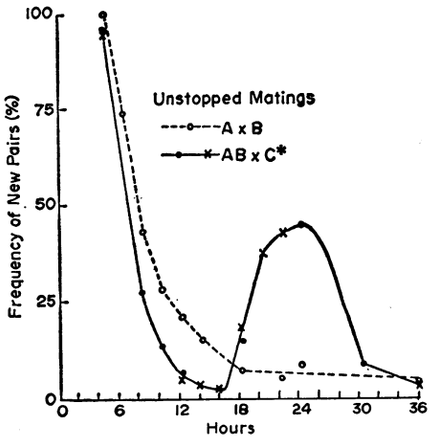

Fig. 2. Frequency of newly formed pairs over a 36-hour period in unstopped matings of AB and C* and a normal cross (A × B). The percentages of new pairs (from attachment through the crescent stage) from two experiments (●———●, x———x) are plotted from the AB × C* cross. For the normal cross these percentages (○----○) were derived from one experiment. Each point is based on observations of 100 pairs (○----○), 300 pairs (●———●), or 500 to 560 pairs (x———x).

exconjugants from two meiotic products contributed from both conjugants, each derived from a different Round 1 pair.

Genomic exclusion is unlike any of the standard forms of sexual reorganization in the ciliated protozoa, that is, autogamy, cytogamy, and normal conjugation (*11*). Since one meiotic product from a single mate is involved, and since homozygosity of both exconjugants is the result, it resembles autogamy more closely than it resembles the other sexual methods in its genetic consequences.

Genomic exclusion can be used to advantage as a rapid means for inducing homozygous diploid lines from heterozygotes. Round 1 exconjugants, which are heterocaryons, can be specifically selected if timed matings are effected between a micronucleate heterozygote and a clone such as C*, and if each of the resulting pairs is isolated into a separate container before the exconjugants come apart. When a pair is isolated in Cerophyl-*Aerobacter* medium and the two exconjugants are kept together, each exconjugant will replicate a population of cells. As the *Aerobacter* are exhausted, the two populations will mate and give rise to several thousand Round 2 pairs which are genotypically identical. Since some unmated cells are also present, sample pairs are removed. Each container will have a homozygous population of pairs, but different containers will have populations of pairs derived from different meiotic products. Screening for desired gene combinations is thus a simple matter of sampling a pair from each of these containers and examining the phenotypes of the cell lines that develop. Each line will be homozygous for a different combination of genes.

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References and Notes

1. See recent reviews by R. F. Kimball in *Biochemistry and Physiology of Protozoa*, S. H. Hutner, Ed. (Academic Press, New York, 1964), vol. 3, p. 243; S. L. Allen, in *Chemical Zoology*, M. Florkin and B. Scheer, Eds. (Academic Press, New York, in press), vol. 1; J. R. Preer, Jr., in *Research in Protozoology*, T. T. Chen, Ed. (Pergamon Press, New York, in press), vol. 3.
2. G. G. Holz, Jr., in *Biochemistry and Physiology of Protozoa*, S. H. Hutner, Ed. (Academic Press, New York, 1964), vol. 3, p. 199.
3. G. W. Kidder and V. C. Dewey, in *Biochemistry and Physiology of Protozoa*, A. Lwoff, Ed. (Academic Press, New York, 1951), vol. 1, p. 323.
4. D. L. Nanney *J. Protozool.* **6**, 171 (1959).
5. S. L. Allen, *Genetics* **45**, 1051 (1960); *J. Protozool.* **10**, 413 (1963); D. L. Nanney, *Genetics* **48**, 737 (1963).
6. S. L. Allen, *Genetics*, in press.
7. D. L. Nanney and M. J. Nagel, *J. Protozool.* **11**, 465 (1964); S. L. Allen, S. K. File, S. L. Koch, *Genetics*, in press.
8. A sample containing several thousand paired or single *Tetrahymena*, or both, in Dryl's physiological salt solution [S. Dryl, *J. Protozool.* **6** (suppl.), 25 (1959)] was concentrated by centrifugation (500*g* for 3 minutes) into a soft pellet, and approximately 0.01-ml amounts of this pellet were diluted and spread on clean glass microscope slides with Nissenbaum's fixative [G. Nissenbaum, *Science* **118**, 31 (1953)]. The slides were stored in 70 percent ethanol before further processing, usually within 2 weeks. They were then further fixed in three parts of 95 percent ethanol to one part of glacial acetic acid for 15 to 20 minutes, hydrated, hydrolyzed in hot 1*N* HCl at 60°C for 15 minutes, and stained in Gomori's hematoxylin at 60°C for 10 minutes [Y. Melander and K. G. Wingstrand, *Stain Technol.* **28**, 217 (1953)]. Cytoplasmic staining was removed by 45 percent glacial acetic acid (23°C, 15 minutes). The preparation was covered, gently blotted, flattened over steam, and ringed with beeswax sealing compound (one part of paraffin to one part of gum mastic to one-fifth part of beeswax). The slides were stored, flat, at 4°C to prevent evaporation and to retard decomposition of the stain. These methods were based on those described earlier by C. Ray, Jr., *J. Protozool.* **3**, 88 (1956) and by C. Wells, *ibid.* **8**, 284 (1961).
9. S. L. Allen, S. L. Koch, C. A. Patrick, in preparation.
10. Esterase-1 and esterase-2 are specified by genes *E-1* and *E-2*. *P-1* controls an acid phosphatase. The esterases and phosphatases are typed by suitable staining methods after starch-gel electrophoresis. A spectrum of mating types is controlled by alleles at the *mt* locus. The *E-1* and *mt* loci are loosely linked; all others, including the *H* serotype locus, are unlinked [S. L. Allen, *Genetics* **49**, 617 (1964)].
11. See T. M. Sonneborn, *Advance. Genet.* **1**, 263 (1947), for a review of the genetic consequences of these processes.

12. Supported by PHS research grant HD-01243. I thank Mrs. Barbara Morrison Licht and Mrs. Sharon L. Koch for technical assistance, Dr. Carolyn Wells for help in developing the cytological methods, and Dr. Eduardo Orias for fruitful discussions.

12 August 1966; revised 25 November 1966

Mongoose Throwing and Smashing Millipedes

Abstract. *African millipedes of the genus* Sphaerotherium *coil into tight spheres when disturbed. Their tough skeletal armor offers protection against some predators, but not against the African banded mongoose* Mungos mungo, *which smashes them by hurling them against rock.*

Millipedes of the order Glomerida (*1*) have the peculiar habit—shared with certain armadillos, pangolins, and some of the familiar isopod Crustacea known as "pillbugs" or "sowbugs"—of coiling into a tight sphere when disturbed (*2*). The behavior is usually assumed to be defensive, but this had never been tested with millipedes. We recently obtained from South Africa mature specimens of two large glomerids of the genus *Sphaerotherium* (Fig. 1), and offered these to several caged predators (*3*). In most cases the millipedes proved invulnerable, as expected. Nevertheless, they did fall prey to one particular enemy, which was singularly adapted to cope with them.

Both species have an unusually hard skeletal shell. The slightest provocation, even a mere tapping of the cage, causes them to coil. Coiling, plus the possession of armor, are the only noticeable means of protection. *Sphaerotherium* lacks the defensive glands found in some other glomerids (*4*) and

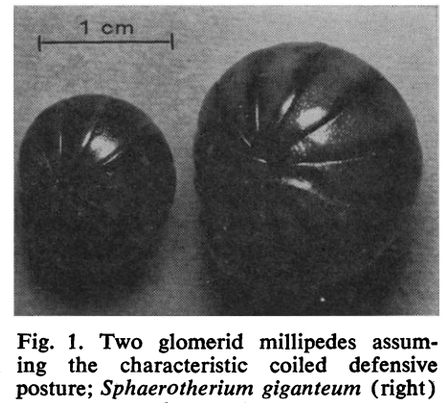

Fig. 1. Two glomerid millipedes assuming the characteristic coiled defensive posture; *Sphaerotherium giganteum* (right) and *S. punctulatum* (left).

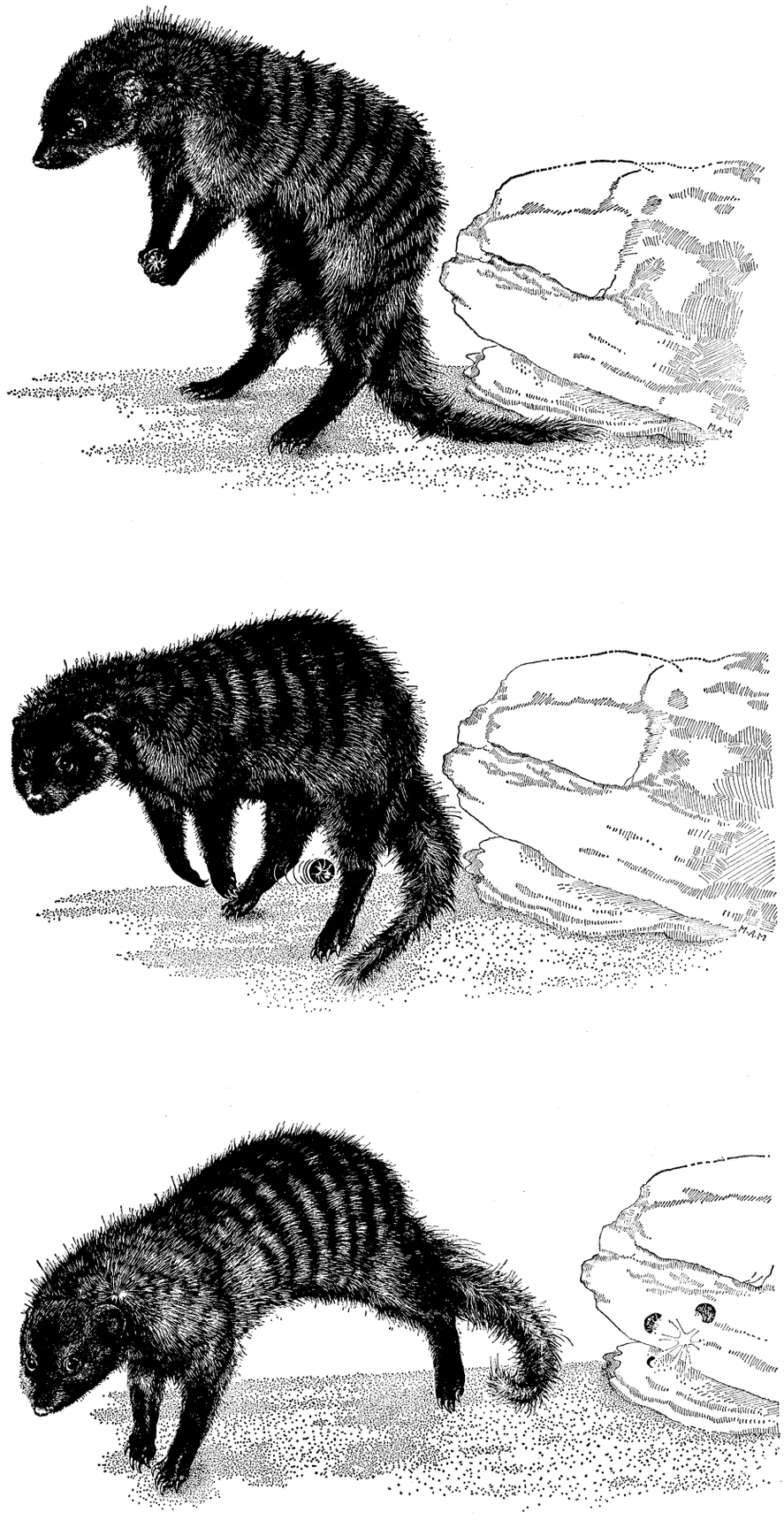

Fig. 2. Three consecutive stages in the hurling and smashing of *Sphaerotherium* by the banded mongoose. Based on still and motion pictures.

in most millipedes of other orders (see *5*).

When a *Sphaerotherium* was offered to ants (*Pogonomyrmex badius*), they swarmed over the coiled millipede and attempted to bite and sting it, but without success. With the millipede's legs and antennae inaccessibly tucked away, the ants could not secure the necessary hold with their mandibles. A blue jay (*Cyanocitta cristata*) and a grasshopper mouse (*Onychomys torridus*) were equally unsuccessful.

The blue jay pecked repeatedly at the millipede, but its bill merely glanced off the hard shell of the prey, flipping it aside. The mouse, a voracious insectivore capable of subduing cockroaches of nearly its own size, seized the millipede in its front paws and attempted to bite it, but had difficulty clamping its jaws on the smooth-shelled sphere; the prey was eventually abandoned, uninjured.

The unexpected occurred in tests with a banded mongoose (*Mungos mungo*). The predator responded instantly to the glomerid, sniffing it, and rolling it about with the paws. It seized it in the jaws, biting upon it with its sharp teeth, but the millipede was neither pierced nor crushed. Suddenly, the millipede was dropped from the jaws and grasped in the front paws. The mongoose backed against a rocky ledge in the cage, assumed a partially erect stance, and—with a motion so quick as to be barely perceptible—hurled the millipede backward between its legs, smashing it against the rocks (Fig. 2). Fatally injured, with its shell broken and its body torn apart, the millipede was promptly eaten.

All told, nine *Sphaerotherium* were offered to the mongoose, on two separate occasions, almost a year apart. The results were virtually identical in every instance. The mongoose was inconsistent in its choice of target surface, but it invariably selected an appropriately hard background and oriented itself properly toward it just before the throw. Sometimes the millipede was not smashed until the second or third attempt.

The banded mongoose lives throughout most of Central and South Africa, and its range overlaps that of *Sphaerotherium* and other glomerids (*2*, *6*). It has a diversified diet and is known to feed on insects, larvae, molluscs, young birds, small rodents, berries, and seeds (*7*). Millipedes may also be taken,

and it seems likely that glomerids are thrown and smashed in nature as they are in the cage. Mongooses also eat eggs, and captive specimens have been known to break these by hurling them (*8*). We found that snails, including such hard-shelled forms as *Neritina reclivata,* and even hazelnuts, are successfully dealt with in the same way. The behavior may occur whenever preliminary pawing and mouthing of a hard "attractive" object fails to yield the edible contents.

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References and Notes

1. Also called Oniscomorpha.
2. R. F. Lawrence, *The Biology of the Cryptic Fauna of Forests* (Balkema, Cape Town, South Africa, 1953).
3. We thank Dr. R. F. Lawrence, Natal Museum, Pietermaritzburg, for sending and identifying the millipedes. The tests with the African mongoose were done at the New York Zoological Park. The other captive predators were housed at Cornell University. The ants were native to Florida, the grasshopper mouse to Arizona, and the jay to New York. Dr. N. Snyder supplied the snails.
4. The small European glomerid, *Glomeris marginata,* produces a sticky defensive secretion; Y. C. Meinwald, J. Meinwald, T. Eisner, *Science* **154**. 390 (1966).
5. References → T. Eisner and J. Meinwald, *ibid.*, **153**, 1341 (1966).
6. J. R. Ellerman, T. C. S. Morrison-Scott, R. W. Hayman, *Southern African Mammals* (British Museum, London, 1953).
7. A. Roberts, *The Mammals of South Africa* (Central News Agency, South Africa, 1954).
8. B. Kinloch, *Sauce for the Mongoose* (Knopf, New York, 1965).
9. Supported by grant AI-02908 from NIH and by the Bache fund of the National Academy of Sciences. Drawings are by M. A. Menadue.

23 December 1966

Primary Oxidation Variation and Distribution of Uranium and Thorium in a Lava Flow

Abstract. *An Icelandic basalt lava flow has a systematic oxidation variation, formed during the initial cooling, with a resultant maximum oxidation just below the center of the lava. The ratio of thorium to uranium shows a clear dependence on this primary oxidation variation. Between-lava comparisons of thorium and uranium may be critically dependent on the position of the samples in each lava.*

Uranium and thorium abundances in basic igneous rocks are receiving considerable attention, largely because of their value in petrogenetic studies and because of the need for a better understanding of the limits of radioactive contributions to geothermal energy sources.

Heier (*1*) interpreted low concentrations of Th and U in Japanese basalts as being a function of the degree of association of orogenic activity with extrusion, and therefore implied a dependence of the concentration of the elements on depth of generation. Heier and Rodgers (*2*) demonstrated the potential of the Th/U ratio to petrogenetic studies by their observation of an increase in the ratio with degree of differentiation of basic igneous rocks. Orogenic activity may result in a greater range of the Th/U ratio across an alkali to tholeiitic suite of lavas than in a similar suite in a nonorogenic area, according to the work of Heier *et al.* (3) on samples from Japan and Hawaii.

Important in any such study, as well as in any detailed interregional (or interlava) comparisons of petrological properties, is, of course, the choice of representative sample material. Major problems include the detection of initial cooling (primary) modification of an initially homogeneous melt and of alterations after cooling (secondary).

Heier and Rodgers (*2*) discussed briefly the secondary alterations relevant to the Th/U ratio, and Heier and Adams (*4*) have suggested that this ratio decreases with increasing metamorphic grade. Examination of a long core of New Hampshire granite by Rodgers and others (*5*) showed the depletion of U by weathering, to a depth of 92 m (300 ft). Hamilton (*6*) also described the effect of weathering on concentrations of U. Nishimura (*7*) examined Th and U across the contact of a granitic intrusion with its host rock, but surprisingly he found no significant variation in the ratio. Heier and Rodgers (*2*) have used the conventional approach in minimizing secondary effects, according to their description of the use of roadcuts to obtain "fresh" samples. On a coarse scale, whether or not a sample is "fresh" can be determined in outcrop (*8*).

Primary modifications are not so readily detectable. Primary differentiation of the Tasmanian dolerite (*9*) did not significantly affect the Th/U ratio, which suggests a system closed to oxygen (*10*). We draw attention here to another primary modification process and describe its effect on concentrations of Th and U and the Th/U ratio.

Watkins and Haggerty (*11*) have described an oxidation variation between the cooling faces of a single 11-m thick Tertiary Icelandic lava, which is a sys-

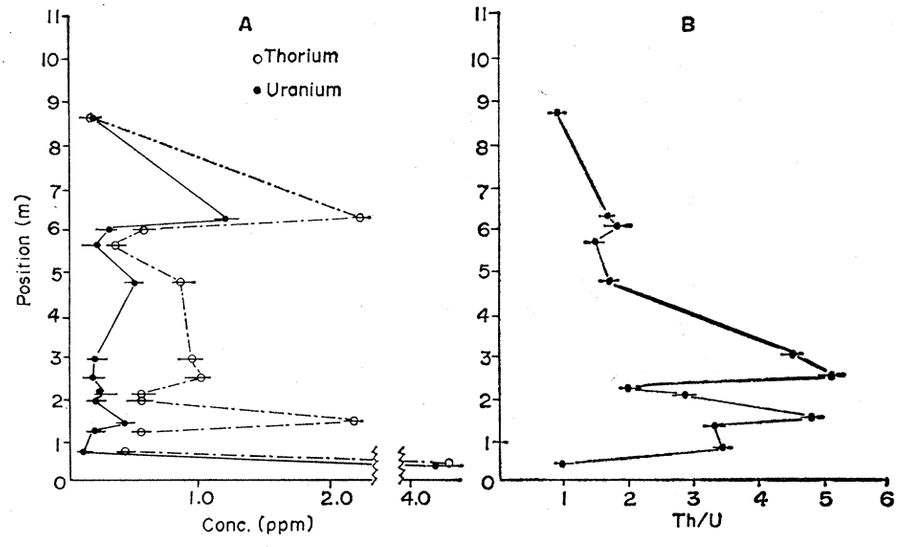

Fig. 1. (A) Variation of the concentration of U and Th with position in the lava flow. (B) Variation of the Th/U ratio with position in the lava flow. Abscissa in both diagrams is distance from base of lava in meters.