matters arising

Large circles on the Earth's surface

AT the 3rd International Conference on Basement Tectonics in Durango on 15–19 May 1978, slides of the large circles in Arizona described by Saul[1] were shown. Several viewers pointed out that the largest circle in Fig. 1 of this paper had also been seen on satellite (Landsat) images, contrary to Saul's experience, and that such images are advantageously used in conjuction with the photographs of raised relief maps.

YNGVAR W. ISACHSEN
The State Education Department,
The University Sate of New York,
Albany, New York 12234

1. Saul, J. M. *Nature* **271,** 345–349 (1978).

SAUL REPLIES—Several investigators have noted that some of the strongest circles are visible on satellite photographs and that some are also discernible on geological and tectonic maps. Satellite photographs of areas that have partial snow cover seem particularly useful. At present the original photomaps made by James Lindsay seem to be the most informative. Lindsay had noted the largest circle in Fig. 1 ref. 1 several years ago as well as strong linear features, some of which have apparently not been noted on more conventional types of coverage. The appearance of these linear features is strongly dependent on the direction of lighting. Several people pointed out circular features in the Canadian Shield, South Africa, East Africa, South Australia and the Himalayan region but these were found on a great variety of maps, photographs and plots, and their identity with those produced by photographing raised relief maps was surmised rather than demonstrated. One of the most interesting was the circular pattern noted by G. A. Kellaway for tin lodes in Cornwall. S. Parker Gay, Jr has identified large circles using the techniques he has developed for viewing geophysical data and topographic information in stereoscopic pairs[2].

JOHN M. SAUL
ORYX,
3 Rue Bourdaloue,
75009 Paris, France

1. Saul, J. M. *Nature* **271,** 345–349 (1978).
2. Gay, S. P., Jr *Geophysics* **36,** 396–414 (1971).

Lifetime of an elliptical ring around Uranus

LUCKE[1] suggests that Uranus' ε ring is composed of particles in elliptical orbits, with slightly different eccentricities and nearly perfect alignment of orbital axes. This model can fit observational data[2–4] obtained in 1977 during the occultation of the star SAO158687. We point out that the model probably works only if the ring is a short-lived configuration, because perturbations due to Uranus' oblateness quickly change the shape of the ring.

If we consider the precession period P of apsidal lines in a ring lying in the planetary equatorial plane, we have

$$P=\frac{4\pi a^{7/2}(1-e^2)^2}{3J_2R^2(GM)^{1/2}}\simeq 98\text{ d} \qquad (1)$$

where M, R, J_2 are the mass, radius and form factor of Uranus respectively (this latter is not well known; we use a typical value of 0.01 (ref. 5)); a and e are the semimajor axis and eccentricity of the satellite particle. If two particles in the ε ring have semimajor axes and eccentricities differing by Δa and Δe, the precession periods differ by a quantity

$$\Delta P=\left(\frac{7\Delta a}{2a}-4\frac{e\Delta e}{(1-e^2)}\right)P \qquad (2)$$

and a randomisation of axis direction is likely to occur in a time

$$T\cong P^2/\Delta P=P/\left(\frac{7\Delta a}{2a}-4\frac{e\Delta e}{1-e^2}\right) \qquad (3)$$

It is unlikely that all pairs of particles have orbits with a and e differing by just the quantity needed to make the denominator of equation (3) very small. Therefore, an upper limit on T may be obtained by assuming $\Delta a\simeq 0$, $e=0.008$ and $\Delta e=0.0005$ (the latter values are chosen to account for the width variation of the ring[1]). We get in this case $T\simeq 6.3\times 10^4\,P\simeq 16{,}900$ yr. A more reliable value of T may be obtained if we consider that interparticle collisions are not likely to allow $\Delta a\simeq 0$; for $\Delta a/a\simeq 10^{-3}$ (which corresponds to the width of the ring), we get $T\simeq 300\,P\simeq 80$ yr.

A similar phenomenon occurs if the ring lies out of the equatorial plane. In this case, the precession of the line of nodes yields, in a time of the order of T, a symmetrical band (with respect to the equatorial plane) that subsequently flattens out as a result of inelastic collisions among particles[6].

We conclude that the ε ring, if composed of particles in elliptical (or inclined) orbits around Uranus, may be only a transient phenomenon, and that the ring perhaps evolves in a way which may be observed.

We thank G. Colombo for useful discussions.

P. FARINELLA
P. PAOLICCHI
Osservatorio Astronomico di Brera, Merate (Como), Italy

A. MILANI
Istituto di Matematica dell' Università, Pisa, Italy

A. M. NOBILI
Istituto di Scienze dell' Informazione dell' Università, Pisa, Italy

1. Lucke, R. L. *Nature* **272,** 148 (1978).
2. Elliot, J. L., Dunham, E. & Mink, D. *Nature* **267,** 328–330 (1977).
3. Bhattacharyya, J. C. & Kuppuswamy, K. *Nature* **267,** 330 (1977).
4. Hubbard, W. B., Coyne, G. V., Gehrels, T., Smith, B. A. & Zellner, B. H. *Nature* **268,** 33–34 (1977).
5. Greenberg, R. *Icarus* **24,** 325–332 (1975).
6. Goldreich, P. *Astr. J.* **70,** 5–9 (1965).

Matters Arising

Matters Arising is meant as a vehicle for comment and discussion about papers that appear in *Nature*. The originator of a Matters Arising contribution should initially send his manuscript to the author of the original paper and both parties should, wherever possible, agree on what is to be submitted. Neither contribution nor reply (if one is necessary) should be longer than 300 words, and the briefest of replies, to the effect that a point is taken, should be considered.

Why should the genome congeal?

A NUMBER of theoretical studies during the past decade have dealt with the problem "Why does the genome not congeal?"[1] that is, why are co-adapted gene combinations repeatedly reshuffled? As a result, specific conditions which may favour recombination have been de-

0028–0836/78/0276—0303$01.00

matters arising

Large circles on the Earth's surface

AT the 3rd International Conference on Basement Tectonics in Durango on 15–19 May 1978, slides of the large circles in Arizona described by Saul[1] were shown. Several viewers pointed out that the largest circle in Fig. 1 of this paper had also been seen on satellite (Landsat) images, contrary to Saul's experience, and that such images are advantageously used in conjuction with the photographs of raised relief maps.

YNGVAR W. ISACHSEN
The State Education Department, The University Sate of New York, Albany, New York 12234

1. Saul, J. M. *Nature* **271**, 345–349 (1978).

SAUL REPLIES—Several investigators have noted that some of the strongest circles are visible on satellite photographs and that some are also discernible on geological and tectonic maps. Satellite photographs of areas that have partial snow cover seem particularly useful. At present the original photomaps made by James Lindsay seem to be the most informative. Lindsay had noted the largest circle in Fig. 1 ref. 1 several years ago as well as strong linear features, some of which have apparently not been noted on more conventional types of coverage. The appearance of these linear features is strongly dependent on the direction of lighting. Several people pointed out circular features in the Canadian Shield, South Africa, East Africa, South Australia and the Himalayan region but these were found on a great variety of maps, photographs and plots, and their identity with those produced by photographing raised relief maps was surmised rather than demonstrated. One of the most interesting was the circular pattern noted by G. A. Kellaway for tin lodes in Cornwall. S. Parker Gay, Jr has identified large circles using the techniques he has developed for viewing geophysical data and topographic information in stereoscopic pairs[2].

JOHN M. SAUL
ORYX, 3 Rue Bourdaloue, 75009 Paris, France

1. Saul, J. M. *Nature* **271**, 345–349 (1978).
2. Gay, S. P., Jr *Geophysics* **36**, 396–414 (1971).

Lifetime of an elliptical ring around Uranus

LUCKE[1] suggests that Uranus' ε ring is composed of particles in elliptical orbits, with slightly different eccentricities and nearly perfect alignment of orbital axes. This model can fit observational data[2–4] obtained in 1977 during the occultation of the star SAO158687. We point out that the model probably works only if the ring is a short-lived configuration, because perturbations due to Uranus' oblateness quickly change the shape of the ring.

If we consider the precession period P of apsidal lines in a ring lying in the planetary equatorial plane, we have

$$P = \frac{4\pi a^{7/2}(1-e^2)^2}{3J_2R^2(GM)^{1/2}} \simeq 98\text{ d} \qquad (1)$$

where M, R, J_2 are the mass, radius and form factor of Uranus respectively (this latter is not well known; we use a typical value of 0.01 (ref. 5)); a and e are the semimajor axis and eccentricity of the satellite particle. If two particles in the ε ring have semimajor axes and eccentricities differing by Δa and Δe, the precession periods differ by a quantity

$$\Delta P = \left(\frac{7\Delta a}{2a} - 4\frac{e\Delta e}{(1-e^2)}\right)P \qquad (2)$$

and a randomisation of axis direction is likely to occur in a time

$$T \cong P^2/\Delta P = P/\left(\frac{7\Delta a}{2a} - 4\frac{e\Delta e}{1-e^2}\right) \qquad (3)$$

It is unlikely that all pairs of particles have orbits with a and e differing by just the quantity needed to make the denominator of equation (3) very small. Therefore, an upper limit on T may be obtained by assuming $\Delta a \simeq 0$, $e = 0.008$ and $\Delta e = 0.0005$ (the latter values are chosen to account for the width variation of the ring[1]). We get in this case $T \simeq 6.3\times10^4\, P \simeq 16{,}900$ yr. A more reliable value of T may be obtained if we consider that interparticle collisions are not likely to allow $\Delta a \simeq 0$; for $\Delta a/a \simeq 10^{-3}$ (which corresponds to the width of the ring), we get $T \simeq 300\, P \simeq 80$ yr.

A similar phenomenon occurs if the ring lies out of the equatorial plane. In this case, the precession of the line of nodes yields, in a time of the order of T, a symmetrical band (with respect to the equatorial plane) that subsequently flattens out as a result of inelastic collisions among particles[6].

We conclude that the ε ring, if composed of particles in elliptical (or inclined) orbits around Uranus, may be only a transient phenomenon, and that the ring perhaps evolves in a way which may be observed.

We thank G. Colombo for useful discussions.

P. FARINELLA
P. PAOLICCHI
Osservatorio Astronomico di Brera, Merate (Como), Italy

A. MILANI
Istituto di Matematica dell' Università, Pisa, Italy

A. M. NOBILI
Istituto di Scienze dell' Informazione dell' Università, Pisa, Italy

1. Lucke, R. L. *Nature* **272**, 148 (1978).
2. Elliot, J. L., Dunham, E. & Mink, D. *Nature* **267**, 328–330 (1977).
3. Bhattacharyya, J. C. & Kuppuswamy, K. *Nature* **267**, 330 (1977).
4. Hubbard, W. B., Coyne, G. V., Gehrels, T., Smith, B. A. & Zellner, B. H. *Nature* **268**, 33–34 (1977).
5. Greenberg, R. *Icarus* **24**, 325–332 (1975).
6. Goldreich, P. *Astr. J.* **70**, 5–9 (1965).

Matters Arising

Matters Arising is meant as a vehicle for comment and discussion about papers that appear in *Nature*. The originator of a Matters Arising contribution should initially send his manuscript to the author of the original paper and both parties should, wherever possible, agree on what is to be submitted. Neither contribution nor reply (if one is necessary) should be longer than 300 words, and the briefest of replies, to the effect that a point is taken, should be considered.

Why should the genome congeal?

A NUMBER of theoretical studies during the past decade have dealt with the problem "Why does the genome not congeal?"[1] that is, why are co-adapted gene combinations repeatedly reshuffled? As a result, specific conditions which may favour recombination have been de-

0028–0836/78/0276—0303$01.00