Letters

Animal Welfare Regulations

The U.S. Department of Agriculture (USDA) will soon propose changes in its Animal Welfare Regulations. These changes will require that regulated institutions provide dog cages high enough for the dog to stand on its rear legs with the front feet resting on the side of the cage, and that, after being in the facility for 21 days, each dog must be given an opportunity for exercise outside the cage for 30 minutes, 5 days of each week. Apparently these changes will apply only to dogs from random sources.

These changes will necessitate the expenditure of great sums of money by medical research and teaching institutions of this country. I know of no scientific proof that these changes will benefit dogs physiologically. The changes are ostensibly being proposed to improve the dogs' psychological well-being. Certainly, it is most doubtful that the dogs will benefit psychologically from these expensive changes.

USDA should be required to prove that these changes are beneficial and needed before they require the scientific community to expend these much needed sums of money. Interested individuals and institutions should be prepared to comment on the proposed changes, which will be published in the *Federal Register*. Comments should be addressed to USDA.

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Orientation of the Pyramids

I would like to agree with Pawley and Abrahamsen (2 Mar., p. 892) that it would be a great pity to overlook any geophysical insights contained in the pyramids. However, before one can draw their deduction—namely, that an ancient meridian laid down at Giza has shifted in azimuth—some additional information is needed. As far as I know, this information does not exist.

The key question is the precision with which the direction of north was (and not merely might have been) determined. This cannot really be argued from the internal consistency of the architecture itself, because measurements could have been transferred from an established azimuth line with a higher relative precision than the absolute precision of the line itself (depending on the techniques). The argument, in this context, that the two meridians of a pyramid were independently aligned, is far from conclusive. Likewise, the agreement in orientation between Cheops' and Chephren's pyramids tells nothing about the absolute direction of north; since they are within a few hundred meters of one another, it is at least as likely that the builders of the younger pyramid took its azimuth from the older one as that it was laid down by new astronomical observations—if the object was esthetic, almost any surveyor would have recommended the first method over the second. What is really needed is evidence from structures sufficiently separated that at least one at each location had to be based on astronomical observations (presumably of a circumpolar star at its extreme diurnal azimuths); this is precisely what is lacking, as the authors state.

Of surviving astronomical observations that we may check for ourselves, absolute naked-eye precision as good as 1′ of arc was unknown until Brahe and Hevelius in the 16th and 17th centuries (*1*). What they were doing was more difficult than the determination of north. Nevertheless, without further evidence we may deem it nearly as probable that geological effects have improved, as that they have worsened, an azimuth line laid down 4500 years ago and which even today is only 3′ to 4′ from true north.

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References

1. A. Pannekoek, *A History of Astronomy* (Wiley, New York, 1961), pp. 214–215, 259.

In the report "Do the pyramids show continental drift?" by G. S. Pawley and N. Abrahamsen, it is stated that "At the time of building [of the pyramids of Giza, about 4500 years ago], the 'pole star' would have been Vega." Vega never was a good pole star, but it was nearest the celestial north pole of rotation (about 4° from it) approximately 13,800 years ago (*1*), or over 9000 years earlier than Pawley and Abrahamsen suggest. Perhaps the star Thuban, Alpha Draconis, was intended; it was nearest the celestial pole in 2832 B.C.

Also it is stated that "there is no direct astronomical method of east-west alignment." On the contrary, one can use two vertical posts, one fixed and one movable, being careful that the line defined by their tops is horizontal. Line the two posts up with the rising sun, and see if this line also passes through the setting sun. On the day that it does, the sun is at an equinox and the line is an east-west line. To allow for the rapid change in the declination of the sun near the time of the equinoxes, make the observations at a spring and at an autumnal equinox.

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References

1. C. H. Smiley and A. M. Khan, *J. Roy. Astr. Soc. Can.* **53**, 249 (1959).

It is pleasing indeed that our report has caused many scientists to think of the possible implications of the misalignment of the pyramids of Giza. The letters from Stephenson and Smiley are but a few of those we have received, a number of which point out the error concerning what would have been the pole star at the time of the building of the pyramids.

Any star within a few degrees of the pole would have sufficed for alignment, and Thuban could well have been the pole star, as Smiley calculates. However, its magnitude is 3½, so it may not have been used in preference to the second magnitude stars Epsilon, Zeta, and Eta Ursae Majoris or Beta Ursae Minoris, which were all within 10° of the pole 6000 years ago. Today we would have to choose Polaris or Beta Ursae Minoris, although the latter is about 16° from the pole. With the simplest of tools—a few long poles,

some string, a stone, an oil lamp, a pointer, a few pegs, and a gallon of water—we are convinced that we could achieve the required accuracy in one night's observation. Our philosophy is if we can devise an experiment today which was equally feasible 6000 years ago, it is fair game to use it to establish the limits of accuracy that could have been achieved. That a different method may have been used is of secondary importance.

To support our contention that an accuracy of 1′ is feasible, we quote from another letter (*1*) We received. O'Keefe writes, "There is no real problem about aligning within 1′. Remember that a rifleman will put 10 shots out of 10 within the innermost ¼-inch circle on a target 50 feet away using open sights and supporting his rifle with his hands. This is just about 1′. Given any kind of firm support, it is possible to point to a much higher accuracy. The last of the astronomers to prefer open sights to telescopic sights was Hevelius; I believe he got an accuracy greater than that of Tycho Brahe, whose errors were about 40″."

O'Keefe also mentions the possibility of transferring a meridian from one set up at a distance, as does Stephenson. O'Keefe further points out that such a reference meridian would differ by 4′ westward if it was only 6 km to the east. The transfer of such a meridian is by far a more difficult task than on-the-spot alignment, but we would be interested in an outline of the procedure and the result of a test experiment. Nevertheless, these questions are secondary to the question of the limit of precision that is feasible, which is Stephenson's main question. Even if we knew the exact procedure used, we could not know its accuracy. We can ask our physics students to repeat certain measurements a number of times in order to establish the standard deviation of the distribution, but only two pyramids were aligned with such accuracy. However, we can examine other constructions. In an article (*2*) in the London *Daily Telegraph*, A. R. Michaelis wrote:

> There is now to hand an all too short announcement that geophysicists in Uzbekistan have observed that the great masonry sextant of the Observatory of Samarkand has moved by 10 minutes of arc since it was built in 1428.
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> This was published in Soviet Weekly on March 30, but did not mention the names of the scientists concerned. The famous observatory in Samarkand, now the oldest in the world, was built by the great Russian astronomer Ulugh Beg, who lived from 1393 to 1449. He was Governor of the Province, wrote poetry and history and loved building in a grand style.

Michaelis then continues by speculating that it would also be worthwhile to make an accurate survey of the constructions of Jai Singh II at Delhi, and at Jaipur, which were built in the 1700's.

Returning to Smiley's second point, there are many reasons why an east-west alignment cannot be accurately established. The angular width of the sun is about ½° and moves nearly 1° in azimuth per day at the equinoxes, giving immediately a ½° error between sunrise and sunset. This azimuthal difference is reversed between the two equinoxes but is not the sole source of error. The east-west condition is met only when the line of sight to the sun is a tangent to the earth's surface. The altitudes of the horizons perturb the result, which is also affected by the refraction of the earth's atmosphere. Furthermore, the refraction effect is different at sunrise and at sunset. It is therefore a fair conclusion that the east-west alignments show instead the Egyptians' well-known ability to construct right angles.

It is obvious that some questions will always be unanswerable and are thus of little use. As in many aspects of archeology, questions must be framed so as to give scope for objective tests. In the present case, if we can establish that a 1′ accuracy was not impossible, then the next stage of the debate is with the geophysicists.

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References

1. J. A. O'Keefe, personal communication.
2. A. R. Michaelis, London *Daily Telegraph*, 16 April 1973, p. 13.

Delayed Publication

The swiftness of publication of the work of the late 19th century scientists cited by Brecher (Letters, 12 Jan., p. 128) is impressive. Nevertheless, in the case of Alfred Russel Wallace's paper "On the law which has regulated the introduction of new species," one must add another parameter—geographical distance. Written in Sarawak