Bottom life under Antarctic ice shelves

WITH reference to the article by Heywood and Light[1], it should be pointed out that the existence of a relatively rich and diversified benthic fauna under an Antarctic ice shelf was first demonstrated by Littlepage and Pearse[2] in 1962 for the Ross ice shelf. During November and December 1961 they collected various representatives of 16 major zoological groups (including the fish *Trematomus* sp.) using traps and grabs inserted through cracks in the shelf ice at distances of 22 and 28 km from the open sea.

As those samples included some typical 'suspension-feeders' (Porifera, Ectoprocta, Sabellida and so on), a water current able to transport the food items evidently exists and may explain the development of a rich bottom fauna under the Ross Ice Shelf. No doubt, such a current is also present under the Shelf ice of King George VI Sound, according to the shape and two openings of this ice covered body of water.

In fact, I see no reason why a substantial bottom fauna should not live anywhere under any floating Antarctic ice shelf, as many Antarctic invertebrates and fish are adaptated to an opportunistic diet (including even necrophagy)[3]. Furthermore, there is no longer any reason to expect a peculiar (specific) fauna under Antarctic ice shelves, as it is now admitted that the Antarctic shelf has been covered by the edges of the Wurmian ice sheet. So, the main biological interest of the Ross Ice Shelf Project (RISP), when drilling at a distance of 450 km from the seaward edge of the Ross Ice Shelf, would be to obtain an insight into adaptations and relationships among the biota of these obscured areas of the Antarctic shelf.

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1 Heywood, R. B., and Light, J. J., *Nature*, 254, 591 (1975).
2 Littlepage, J. L., Pearse, J. S., *Science*, 137, 679 (1962).
3 Arnaud, P. M., *Third Symposium on Antarctic Biology, Washington* (in the press).

HEYWOOD AND LIGHT REPLY—We are grateful to Arnaud for drawing our attention to the paper by Littlepage and Pearse, an unfortunate oversight on our part. We note from this paper the *Trematomus* sp. was found by DeVries and Kooyman. We agree of course with the ecological comment of Arnaud. We prefer, however, to keep an open mind on whether a substantial bottom fauna can live anywhere under a floating Antarctic ice shelf—the problems of obtaining enough food at a distance of 450 km from the open sea could be far greater than when merely 28 km away. We believe this justifies our remarks that the first biological aim of RISP is to determine whether a biome can exist at a considerable distance from the open sea, and that a biome found under ice 100–500 m thick, at least 100 km from the open sea, is "remarkable".

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Random packing of equal spheres

THE recent article of Gotoh and Finney[1] has drawn my attention to this interesting problem. I have been impressed by the amount of experimental work carried on in this field, but at the same time I am wondering why similar experimental work has not been done—as far as I know—on the theoretically simpler problem in two dimensions to provide some evidence. I have also noticed several more or less explicit pleas to mathematicians to 'invent a statistical geometry'. None of the authors seems aware that such a geometry does indeed exist. It is usually called "integral geometry" (see, for example, ref. 2) and its methods should certainly be relevant to this problem.

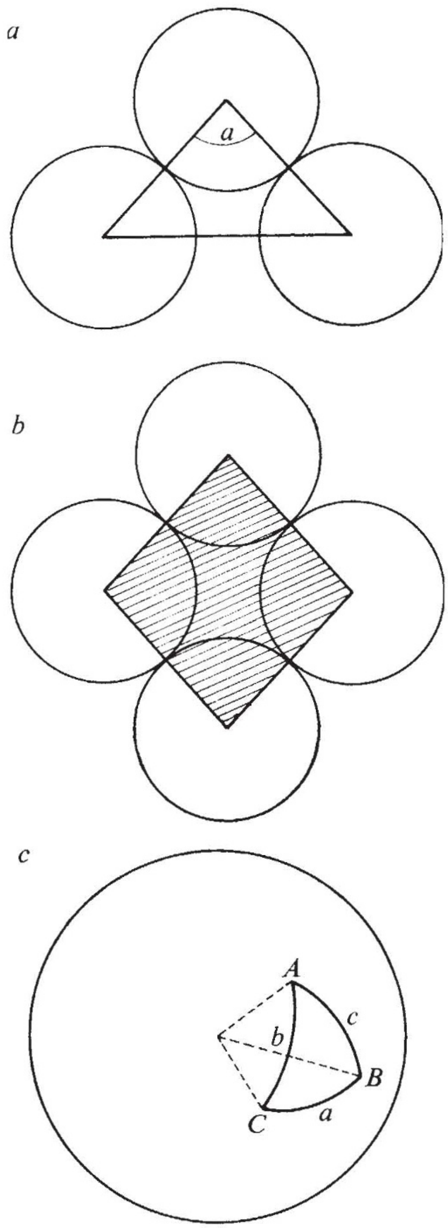

Fig. 1 Packing of circles and triangles.

The origin of integral geometry can be traced back to the famous 'Buffon's needle' problem. A needle of length l is thrown on a board ruled with parallel lines at distance d. One can show that the average number n of contacts of the needle with the lines is

$$n=(2/\pi)(l/d) \qquad (1)$$

Integral geometry has several theorems such as (1) in which the constant $2/\pi = 0.6366197\ldots$ appears. Could this be the "maximum packing density" given in ref. 1 as 0.6366 ± 0.0008 and 0.6366 ± 0.0004 in two different experiments? It is certainly a conjecture worth pursuing.

In the meantime I would like to suggest an elementary explanation of the random loose packing density. Let us start from the two-dimensional case.

Circles and triangles take the place of spheres and tetrahedra. In the language of Gotoh and Finney we have a triangle—formed by an arbitrary circle and two supporting circles—which is completely specified by the angle a (see Fig. 1). To compute the packing density it is convenient to add a circle on the bottom to make the drawing more symmetrical. We can then easily see that the packing density of the configuration is the area of one circle divided by the (hatched) area of the parallelogram. Assuming a uniform probability density for the angle a, the average area A of the parallelogram is then

$$A = \frac{\int_{\pi/3}^{\pi/2} 4r^2 \sin a\, da}{\int_{\pi/3}^{\pi/2} da} = (12/\pi)r^2 \qquad (2)$$

The limit $\pi/3$ corresponds to the case of the two supporting circles in contact; angles greater than $\pi/2$ give a configuration equivalent to one rotated by 90°. The average packing density d is then

$$d=(\pi r^2/A)=(\pi^2/12)\sim 0.8225 \qquad (3)$$

All configurations being taken as equally likely with no correlations this density