

glands resemble each other or may be even reduced to an identical fundamental property of the specific tissue, not necessarily connected with its vital organization in the living cell.

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### Lung Lining in Bird, Reptile and Amphibian

THE lungs of mammals are lined with a film of lipoprotein, which has the function of reducing the tension of the sharply curved alveolar surface<sup>1</sup>. A similar film was also found to exist in the pigeon and the frog<sup>2</sup>. Miller and Bondurant<sup>3</sup> and Klaus *et al.*<sup>4</sup> have, however, concluded as a result of a study of the surface properties of saline extracts of minced lung from turtle, frog, and pigeon that a distinctive surface-active material exists in mammalian lungs only. We have, therefore, re-examined the question.

The species used were the chicken (*Gallus*), slow-worm (a legless lizard, *Anguis fragilis*), and clawed toad (*Xenopus laevis*). The lungs of these were compared with those of mammals; a summary of the findings is given in Table 1. The methods used have been described elsewhere<sup>2,5,7</sup>.

Small bubbles, squeezed from a fragment of mammalian lung into a hanging drop of air-saturated water, usually contract somewhat and then remain stable. The ratio of final (stable) to initial surface area is called the stability ratio; for bubbles initially between 36 $\mu$  and 60 $\mu$  in diameter the mean stability ratio is about 0.7. Ordinary bubbles of this size, for example those formed in blood, contract and disappear in a few minutes. In our experiments we found that bubbles squeezed from fragments of the bird, reptile, and amphibian lungs were as stable as those from mammalian lungs; the smallest of them were stable enough and small enough to show Brownian motion.

When bubbles (say 100 $\mu$  in diameter) from mammalian lung are immersed in de-aerated water under a glass slide, they first flatten as the air dissolves and the surface tension falls, and then suddenly resume at an almost spherical shape; in the latter process, the equatorial diameter is reduced by about 10 per cent. The phenomenon is known

as 'clicking', and repeats itself rhythmically as the bubble dissolves; it demonstrates<sup>6</sup> that the bubble surface has a free energy in excess of the product of its area and surface tension. Bubbles from bird lung behaved in de-aerated water exactly like those from mammalian lung; those from the slow-worm showed less prominent 'clicking'; while those from toad lung did not 'click', but contracted steadily.

A mammalian lung may be made to collapse to an air-free state by exposure to a vacuum followed by sudden restoration of atmospheric pressure. If it is then re-inflated, it retains much of the air forced into it, and fragments from it give stable bubbles like those from fresh lung<sup>2</sup>. We found that when chicken lung was collapsed, and air was injected into the tissue, fragments from the lung when squeezed into air-saturated water gave bubbles as stable as those from mammalian lung. The slow-worm and toad lungs, on the other hand, when collapsed and re-inflated, retained little air, showed a strong tendency to collapse again spontaneously, and yielded bubbles much less stable than those from fresh lungs.

If washings from mammalian lungs are carefully freed from any bubbles they may contain, and are then frothed by blowing air from a needle into the liquid<sup>7</sup>, they form bubbles with stability ratio usually in the range 0.5-0.9. Injection of saline into the bird lung tissue, and recovery of the saline by squeezing, produced washings resembling in this respect those from mammalian lung. Washings from the slow-worm and toad lungs, however, provided few stable bubbles.

It is evident from these findings that a surface film capable of reducing to a large degree the tension of the surfaces of the fine air spaces of the lung exists in the bird, reptile and amphibian, as well as in mammals. The lung lining film of the toad is, however, less elaborate than that of the slow-worm, which is in turn less elaborate than that of the bird or mammal. The failure to re-form a complete film after collapse and re-inflation, and the poor stability of bubbles from lung washings, in the toad and slow-worm show that these have only a small reserve of the saline-dispersible 'lining complex' from which the lining film is formed; the smallness of this reserve would explain the weakness of the surface film on the extracts of amphibian and reptile lung studied by other workers<sup>3,4</sup>. Our experiments provide no evidence as to whether the bird has a greater or smaller supply of complex than has the mammal.

The curvature of the surfaces of the air spaces in reptile and amphibian is less than in mammal or bird, and it is not unexpected that their supply of surface-active agent should be less than in the warm-blooded classes. In the mammal, the alveoli would collapse if the surface film were absent; or, if the lung were held open by air pressure, transudation from the blood capillaries into the alveoli would occur. In the bird, collapse of the lung may in part be prevented by its more rigid structure (though it can, as stated here, be collapsed artificially); to prevent transudation, however, a surface film is even more necessary than in the mammal, because the curvature of the walls of the air capillaries of the bird is even sharper than that of the walls of the mammalian alveoli.

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Table 1. PROPERTIES OF BUBBLES FROM THE LUNGS OF MAMMAL, BIRD, REPTILE AND AMPHIBIAN, COMPARED WITH THOSE OF ORDINARY BUBBLES

	Bubbles from lungs of:			Toad	Bubbles in blood, etc.
	Mammal	Chicken	Slow-worm		
Stability ratio of bubbles from fresh lung (means of batches of 30)	0.60-0.87	0.74 0.78	0.73 0.80	0.81 0.82	0.0
Brownian motion	+	+	+	+	-
Clicking (per cent decrease in equatorial diameter)	10%	10%	2%	nil	nil
Stability ratio of bubbles from lung collapsed once and re-inflated (means of batches of 30)	0.60-0.87	0.73 0.80	0.16*	0.06 0.29 0.39	0.0
Stability ratio of bubbles from lung washings (means of batches of 10)	0.5-0.9	0.6 0.7	0.0	0.1 0.1	0.0

\* Mean of batch of five bubbles.