

## THE RATE OF EXCRETION OF INDIAN INK, INJECTED INTO THE LUNGS

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As a control to experiments on the excretion of radio-opaque dusts [Barclay, Franklin & Macbeth, 1937 *b*], insufflated into the lungs, we have studied the rate of elimination of injected Indian ink.

### METHODS AND RESULTS

All the experiments were done on cats' lungs, as the cat is the species which we have used for our parallel work. In some cases we used the isolated lungs *cum* trachea preparation previously described [Barclay *et al.*, 1937 *a*], in others animals decerebrated after trephining.

In the first isolated preparation a small portion of the base of the right lung was cut off to expose a bronchiole *c.* 1 mm. in diameter. A small amount of Indian ink was injected into the bronchiole and the cut surface clamped off. The preparation was then placed in a bath of Ringer's solution at 37° C. with the end of the trachea above the surface of the fluid. At the end of 18 min. from the time of injection the observer, looking down the trachea, saw the ink travelling spirally (clockwise, viewed from above) along the main right bronchus towards the bifurcation of the trachea. It reached the bifurcation at a point less than half way across to the sternal side, and hence [Barclay *et al.*, 1937 *a*] was directed back towards the dorsal surface of the trachea. This was at 19 min. from the time of injection, and the distance travelled was 4 cm., measured in a straight line. In the trachea the ink was carried spirally (clockwise, viewed from above) upwards, turning through 200° and passing 8 cm. up the trachea in 6 more minutes.

In a second preparation a similar injection was made into a bronchiole 4.3 cm. from the bifurcation of the trachea. A trace of ink appeared at

the bifurcation in 15 min., and the bulk in 24 min. A second injection, into another bronchiole, took 8 min. to travel 2.4 cm. to the main right bronchus, and subsequent dissection showed that no ink remained at the site of injection or anywhere along the course.

In a third preparation injected ink took 14 min. to reach the bifurcation from a bronchiole, 4.7 cm. distant, in the right lung. A similar injection, made after this, into a bronchiole of the left lung, took 22 min. to come nearly to the bifurcation. The ink was seen to travel spirally (clockwise, viewed from above) within the main left bronchus; the distance travelled, measured in a straight line, was 4.5 cm., and no trace of ink remained behind.

If we take the average of the above figures, we find that the ink travelled in the lung *c.* 0.25 cm. per min., measured in a straight line. In the trachea the rate was much greater and averaged in all our experiments *c.* 1 cm. per min. Seeing that the mucous blanket cannot be materially increased in thickness without inactivating the cilia, and that the circumferences of two bronchi together exceed that of the tube into which they unite, the increased rate of passage along the trachea is comprehensible. As the normal secretion of mucus was unlikely to continue for very long in the isolated preparation, and as in other respects also such a preparation was likely to be less efficient than the lungs *in situ* in the living animal, there was every chance that the rates given above would be less than those occurring under more physiological conditions.

Tests made in two decerebrate cats showed this to be indeed the case. A cannula was tied into the trachea of each animal, so the whole length of the trachea was not available for the experiment. In the first cat an incision was made between two ribs into the right pleural cavity, and a moderate amount of Indian ink was injected sub-pleurally into the right lung. Artificial respiration was applied while the skin incision was being closed, in order to prevent a pneumothorax. Within 14 min. from the time of injection a large part of the ink had reached the distal end of the tracheal cannula. The actual distance travelled was not measured *in vivo* in this case, but in the excised lungs *cum* trachea the site of injection was 4 cm. from the tracheal bifurcation and the distal end of the cannula was 5 cm. from the same point. In the intact animal, both these distances would have been appreciably greater, for the trachea and lungs both retracted on removal from the body. In the second cat an injection was made into the right lung through the thoracic wall without any opening of the pleural cavity. The position of the needle was observed by means of X-ray screening, and it corresponded very closely with its position

during the subsequent injection of a radio-opaque mixture. The radio-opaque injection was just sub-pleural, as observed by screening and also in radiographs of the intact animal and of the excised lungs. It is, therefore, probable that the Indian ink injection too was sub-pleural; in support of this view there is the further fact that a certain amount of the injected ink was still present just below the pleura in the excised lung. In this second cat, as in the previous one, a large portion of the ink was at the distal end of the tracheal cannula within 14 min. The distances travelled were 2.6 cm. within the lung and 7.0 cm. up the trachea, as measured after excision. The tracheal distance, measured in a lateral radiograph taken *in vivo* about half way between inspiration and expiration, was 9 cm.; the intrapulmonary distance could not be similarly measured, because the bifurcation did not show up clearly in the one sagittal radiograph taken.

It is unlikely that the injections in these two cats went directly into bronchioles, for there was no sign of this on post-mortem dissection; also, the Indian ink did not come up all together, as it did when injected direct into bronchioles in the isolated preparations, but in divided portions. There was, therefore, more to be done in the decerebrate animals than in the isolated preparations in order to carry the ink from the lungs up the trachea, yet the rates of travel in the living animal were relatively greater.

#### SUMMARY

Indian ink, injected into fine bronchioles in the isolated lungs *cum* trachea preparation of the cat, travelled on an average 1 cm. in 4 min. in the lungs, and 1 cm. in 1 min. in the trachea.

Indian ink, injected sub-pleurally into the lungs of decerebrate cats, was carried to the distal end of the tracheal cannula in 14 min. The distance travelled, estimated from a comparison of radiographic and post-mortem measurements, averaged about 4 cm. in the lungs and 8 cm. in the trachea.

All the above distances are straight measurements from point to point. As the movement within the trachea and bronchi is a spiral one, the actual distances travelled by the ink were considerably greater.

#### REFERENCES

- Barclay, A. E., Franklin, K. J. & Macbeth, R. G. (1937 *a*). *J. Physiol.* **90**, 347.  
Barclay, A. E., Franklin, K. J. & Macbeth, R. G. (1937 *b*). (To be published.)