then variation with respect to $\mathbf{v}$ leads to $(m\mathbf{v}+e\mathbf{A}/c)=0$, equivalent to the London equation, which is plainly not the correct equation of motion.

A similar difficulty with action principles in eulerian variables is well known in fluid dynamics[8]. There the kinetic and potential energies are both naturally expressed in eulerian variables and (ignoring entropy changes for simplicity) the action is

$$I=\int\int\left(\tfrac{1}{2}\rho\mathbf{v}^2-U(\rho)\right)\mathrm{d}^3x\,\mathrm{d}t \quad (8)$$

where ρ is the density and $U(\rho)$ the internal energy of the fluid. The principle of least action for an independent variation $\delta\mathbf{v}$ would lead to the equation of motion $\mathbf{v}=0$. But obviously one should not treat $\mathbf{v}$ and ρ as independent, for they are linked by the equation of continuity

$$\frac{\partial\rho}{\partial t}+\nabla\cdot(\rho\mathbf{v})=0 \quad (9)$$

However, when this is introduced as a constraint, through an undetermined multiplier λ one obtains $\mathbf{v}=\nabla\lambda(\mathbf{x},t)$ which is still too restrictive, since it permits only irrotational flow. Hence the problem with the eulerian action principle is not simply that the variables are interdependent but involves something more subtle.

The essential point appears to be[9] that in using the principle of least action to calculate equations of motion, the displacements $\delta\mathbf{x}$ must vanish at the initial and final times. This is more stringent than the requirement that the eulerian variables $\delta\rho$, $\delta\mathbf{v}$ should vanish for that does not exclude an interchange of indistinguishable fluid elements. To allow for this, one must impose a further constraint on the velocity:

$$\frac{\partial\alpha}{\partial t}+\mathbf{v}\cdot\nabla\alpha=0 \quad (10)$$

for an arbitrary function $\alpha(\mathbf{x},t)$. This constraint, first introduced by Lin[10], has the effect of labelling each fluid element and is necessary and sufficient to make the principle of least action valid in eulerian variables.

It is clear that an equivalent of the Lin constraint should be incorporated into Edwards' argument. When this is done one obtains equations similar to equation (1) describing a perfect conductor, not the London equation for a superconductor.

In his response[11], Edwards appears to accept the force of this criticism but maintains that there may neverthless be some classical systems for which it is correct to omit the Lin constraint. (*Exactly* why omitting it produces the correct result for superconducting electrons is not clear, but is presumably related to the impossibility of following exact trajectories in quantum systems.) Edwards suggests that high-temperature plasmas may be a case in point and he refers to the existence of filamentary magnetic structures in plasmas (as occur in type II superconductors). There are, however, several possible explanations for these structures.

The reference to the behaviour of magnetic fields in plasmas gives a final intriguing twist to the controversy. Some years ago I proposed a theory of relaxation of turbulent plasmas[12], for which there is now considerable experimental support[13]. In that theory, the plasma relaxes to a final state satisfying $\nabla^2\mathbf{B}+\mu^2\mathbf{B}=0$. This has a superficial resemblance to equation (3) but in this case μ^2 is a macroscopic parameter, related to the size of the system, and its sign is the opposite of that needed to describe the Meissner effect! □

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100 years ago

NEW OR RARE ANIMALS IN THE ZOOLOGICAL SOCIETY'S LIVING COLLECTION

THE KOALA (*Thascolarctos cinereus*). For many years it was deemed impossible to keep the Koala, or Native Sloth of Australia, alive in captivity. Great and persistent efforts, it was said, had been made by many persons in various part of the Australian Colonies to induce this curious little animal to submit to confinement. But as they never survived long, even under the most favourable conditions in Australia, it was hopeless to expect that we should ever see this animal living in London.

These prophecies, however, like other forebodings on more serious subjects, have turned out to be fallacious. In April, 1880, the Society acquired a living example of this animal in excellent health. It had been brought home from Australia along with a large barrel of the dried leaves of one of the gum-trees (*Eucalyptus*), upon which scanty diet, however, it appeared to have thriven well during the voyage. On being placed in a compartment of a room fitted up specially for it with branches to climb about upon, and supplied with fresh gum-tree leaves and a little bread and milk, it continued to prosper admirably, until it lost its life by an untoward accident.

The specimen had not been replaced until May last, when a second example, from which our Fig. (24) has been taken, was acquired.

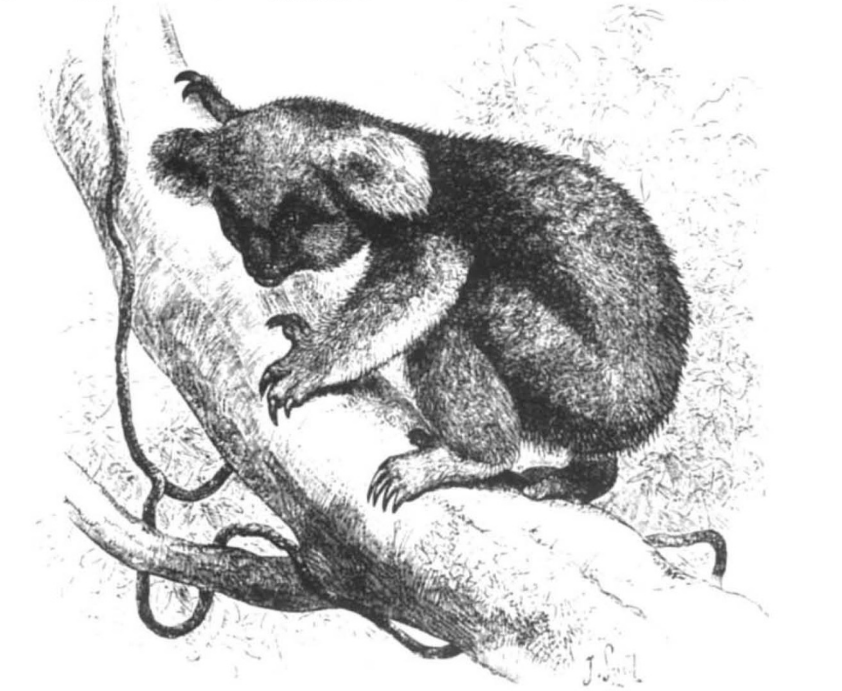

FIG. 24.—The Koala.

The Koala is apparently confined to the south-east of Australia. It is recluse in its habits, hiding in the day time in the dense foliage of the eucalypti or native gum trees, so that without the aid of the natives it is not easily detected. By these, however, it is readily discovered, and captured by the aid of their waddies or throwing-sticks. It is exceedingly tenacious of life, clinging to the branches after being shot until perfectly dead.

The natives of Australia are said to be very fond of the flesh of the Koala, and readily join in the pursuit of it; they examine with wonderful rapidity and minuteness the branches of the lofties, gum tree, and upon discovering a Koala, they climb the tree with as much ease and expedition as a European would mount a tolerably high ladder. Having reached the branches, which are sometimes forty or fifty feet from the ground, they follow the animal to the extremity of a bough, and either kill it with a tomahawk, or take it alive. From *Nature* **26,** 604, 19 October 1882.

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