Conklin's volume, "The Direction of Human Evolution", which was published in 1921, and which offers much detailed evidence in support of Dr. Waddington's position.

At the 1940 Christmas meeting of the American Association for the Advancement of Science in Philadelphia, the Section on Historical and Philological Sciences held a symposium on "Science and Ethics". Participating in this symposium, over which I had the honour of presiding, were Profs. Herrick, Conklin, Holmes, Teggart, Mackay, Galdston, de Santillana, Sigerist, Sarton, Shryock, Gerard, Birkhoff, and Mayer. At the conclusion of the discussion, the section unanimously agreed to a descriptive statement which seems justifiably inducible from data now available. While taking into account criticisms of the intellectual validity of traditional ethical statements as raised by psychology, anthropology, dialectic materialism, or logical positivism, the statement of these American men of science indicates that they are willing to agree, at our present "level of analysis" as Dr. C. H. Darlington[5] might put it, that certain biological generalities have moral consequences. The recognition by conscious individuals of these consequences, results in "ethical principles as actual psychological compulsions derived from the experience of the nature of society."

The statement may be put in a formal manner: The probability of survival of a relationship between individual humans, or between groups of humans, increases with the extent to which the relationship is mutually satisfying and advantageous. This principle was first formulated in this manner at a memorable seminar in the Santa Cruz redwoods in July, 1939, when the Pharmacology Laboratory of the University of California entertained Profs. Conklin, Herrick, and Olof Larsell.[6] It was then appreciated that this formulation is merely a special case of the more general biological principle: The probability of survival of individual, groups, or species of living things increases with the degree with which they can and do adjust themselves harmoniously to each other and to their environment.

The ethical significance of this general principle appears in relation to the common biological urges for survival and satisfaction. Consciousness of the operation of this generality suggests the wisdom of such altruistic, considerate, and magnanimous conduct as is intuitively considered 'good' in all ethical systems. The social customs and conventions now with us have so far exhibited survival value in a Darwinian sense. We may apply evolutionary criteria to them and attempt the formulation of a *modus operandi*. Such a formulation constitutes the statement. The principle operates, whether we as humans are conscious of it or not. To promote the conscious appreciation of such natural principles is part of the business of science. There appears to be scientific justification for what philosophers have maintained for centuries, namely, that knowledge of ourselves and of our environment has in itself ethical significance and moral consequence.

CHAUNCEY D. LEAKE.
Medical School,
University of California,
San Francisco.
November 22.

[1] NATURE, **148**, 270 (1941).
[2] *Scientific Monthly*, **49**, 295 (1939).
[3] *Scientific Monthly*, **49**, 99 (1939).
[4] *Science*, **90**, 117 (1939).
[5] NATURE, **148**, 344 (1941).
Scientific Monthly, **53**, 133 (1941).

Mathematical Theory of Population Movement

AMONG the obvious motives of mankind are the tendencies to seek company and to seek living-space. If we were to regard these tendencies as being in simple opposition to one another, we should expect the population to be able to remain uniformly spread over any uniform piece of land; and the familiar contrast between town and country would then appear, to the theoretical mind, as a mystery requiring explanation. We may, however, seek a hint as to why people concentrate into towns from Sir James Jeans's theory of why matter concentrates into stars[1]. For his theory is also concerned with two opposing tendencies: to draw together by mutual gravitation and to spread out by pressure.

Let ρ denote the density of the astronomical matter, supposed initially uniform, let $s = \delta\rho/\rho$ be its concentration at any time t and place, let p be its pressure and γ the constant of gravitation. Then Jeans showed that deviations from uniformity occur in accordance with the equation

$$\frac{d^2 s}{dt^2} = 4\,\pi\gamma\rho s + \nabla^2\left(s\frac{dp}{d\rho}\right). \quad . \quad . \quad . \quad (1)$$

The essence of Jeans's theory is that the opposition between gravitation and pressure is not simple: the former is represented by a term in s, the latter by a term in $\nabla^2 s$. These considerations led me to inquire whether the existence of towns could be explained by

$$\frac{ds}{dt} = \gamma\rho s + \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\left(s\frac{dp}{d\rho}\right). \quad . \quad . \quad (2)$$

in which ρ, supposed initially uniform, is the number of persons per square kilometre, $s = \delta\rho/\rho$ as before, x and y are horizontal co-ordinates on a flat portion of the earth, γ is a constant expressing gregarious attraction, and p is called pressure of population. The social equation (2) has been made of viscous type by replacement of the astronomical d^2s/dt^2 by ds/dt.

Whereas Jeans began the astronomical theory with γ known and p clearly understood, and thence deduced the spacing of the stars, we have to begin the social theory at the other end, and work backwards to find out more clearly what γ and p mean. Equation (2), in which $dp/d\rho$ is an unknown constant, explains why the population does not remain uniformly spread. For the amplitude of a standing wave of s either grows or diminishes, according as the wave-length is greater or less than a critical length. It can be deduced that $dp/\gamma d\rho$ is of the order of magnitude of the ratio of the number of persons in a country to the number of towns in it. Further, $dp/d\rho$ is seen to play the part of a diffusivity in equation (2). From the observed time of dispersal of concentrations having diameters much less than the distance between towns, it can be estimated that $dp/d\rho$ is of the order of 10^5 cm.^{2} sec^{-1}. Whence it follows that γ is of the order of 10 or 10^2 cm.^{2} sec.$^{-1}$ person^{-1} for normal people.

A fuller account is ready for publication as part of a book.

LEWIS F. RICHARDSON.
38 Main Road,
Castlehead,
Paisley.
Dec. 3.

[1] Jeans, Sir James, "Astronomy and Cosmogony" (Camb. Univ. Press, 1929).