non-adaptive characters show no relation to differences of habit or environment, and, as a rule, develop directly without recapitulation. I have instanced the adaptive characters of Pleuronectidæ (flat-fishes) on one hand and their specific and generic characters on the other. The adaptive characters of flat-fishes exhibit one of the most remarkable cases of metamorphosis and recapitulation in the whole field of zoology, while the various peculiarities of the scales, as examples among specific and generic characters, show neither recapitulation nor any relation to habits and conditions of life. Thus, instead of agreeing that there is only one kind of character, I find it necessary to distinguish three kinds, one due to the effect of an external stimulus on the individual, and not apparently inherited, and two kinds which are hereditary. J. T. CUNNINGHAM.

Chiswick, December 31.

Optical Observation of the Thermal Agitation of the Atoms in Crystals.

ACCORDING to the theory of specific heats developed by Debye, Nernst, and others, the thermal energy of a solid is made up of the energy of elastic vibrations in its material, the frequencies of such vibrations ranging from very small values up to a maximum limit determined by the ultimate molecular or atomic structure. On this view it is clear that at ordinary temperatures the density of a solid, and therefore also its refractive index if it be of transparent material, would vary arbitrarily from point to point about its mean value. In other words, a transparent crystal cannot be regarded as optically homogeneous even with reference to the comparatively long waves which constitute ordinary light. It follows that a certain proportion of the energy of a beam of light traversing the medium would be deviated laterally and appear as scattered light, the intensity of such scattering being a measure of the thermal agitation within the crystal. That some such effect must occur has already been pointed out by Sir Joseph Larmor (*Phil. Mag.*, vol. 37, p. 163, 1919), but no theoretical discussion of its magnitude appears so far to have been put forward. It has occurred to the present writer that the effect to be expected may be found in the following way:—If the principles of statistical mechanics and the equipartition of energy were applicable in the case of solids, precisely the same considerations which determine the molecular scattering of light in fluid media would enter here as well, and the scattering coefficient would be given by the Einstein-Smoluchowski formula

$$\frac{\pi^2}{18}\cdot\frac{RT\beta}{N\lambda^4}\cdot(\mu^2-1)^2(\mu^2+2)^2,$$

where β is the compressibility of the solid, μ is its refractive index, λ is the wave-length of the light, and R, T, N are the constants of the kinetic theory. It is known, however, that the heat-content of solids at the ordinary temperature is much less than that indicated by the equipartition principle, the deficiency being most marked for substances, such as diamond, having a high "characteristic temperature." The scattering coefficient given by the preceding formula must therefore be diminished in the ratio which the actual heat-content at the temperature of observation bears to the heat-content indicated by the equipartition principle. This correction-factor may be found from the experimental data for the specific heats at low temperatures given by Nernst, Lindemann, and others.

Calculations made in the way indicated above show that transparent quartz should scatter light $9\frac{1}{2}$ times as strongly as dust-free air at normal temperature and pressure. A scattering of approximately this magnitude in clear quartz was detected photographically by R. J. Strutt (now Lord Rayleigh) (Proc. Roy. Soc., vol. 95, p. 495, 1919), but was ascribed by him to inclusions which he assumed were present in the crystal. It is clear from what has been said above that the effect observed by him was actually due to the thermal agitation of the atoms in the crystal. The present writer has succeeded in demonstrating the scattering of light in clear quartz by direct visual observation. For this purpose a block of the crystal with smooth polished faces is immersed in a tank of clean distilled water to minimise surface-reflections and a converging lens is used to bring a beam of sunlight to a focus within the crystal. The blue track of the beam within the crystal may then be readily observed, and its intensity can be judged by comparison with the scattering of the beam in saturated ether vapour. The writer has had the pleasure of exhibiting the phenomenon to Sir W. J. Pope and other distinguished callers at his laboratory.

Transparent rock-salt which has a low characteristic temperature and shows a marked "Debye-effect" in experiments on X-ray reflection exhibits a very strong scattering of ordinary light. The increase of the scattering with rise of temperature may readily be observed with it. C. V. RAMAN.

210 Bowbazaar Street, Calcutta, November 19.

A Fossil Buttercup.

WHEN we examine a catalogue of fossil plants, such as that for North America recently published by Knowlton, we are struck by the enormous number of recorded species, and readily receive the impression that the flora of former ages is quite well known. It is only when we make a more critical investigation that we perceive the great gap in our present knowledge. We do, perhaps, know a fair proportion of the trees and deciduous-leafed shrubs of a number of geological periods, but when we look for the herbaceous flora the limitations of our knowledge at once appear. Thus the Ranunculaceæ, an extensive family in the present North American flora, do not furnish a single definitely recorded fossil in the same area. Dawson in 1875 vaguely referred to a Thalictrum, without specific name, supposedly from the Eocene, but it is not to be taken seriously. Schenk thought the fossil genus Dewalquea presented a certain analogy with Helleborus, but it is now referred to quite another family. It is, of course, impossible to suppose that the Ranunculaceæ were absent from North America during Tertiary times; they simply must have escaped preservation or observation. To those who would see in the geological record a proof that herbaceous plants did not exist in the past, or were extremely rare, we can only reply that the record as it stands proves too much. To accept it at its face-value postulates the impossible. The general proposition that the herbaceous flora is, *on the whole*, more recent than the woody may be valid, and has much to recommend it.

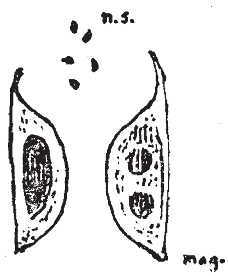

FIG. 1.—Achenes of *Ranunculus florissantensis.*

With regard to the Tertiary Ranunculaceæ of North America, we can fortunately rescue them from utter oblivion. Several years ago I fcund some slabs of Miocene shale at Florissant, Colorado, plentifully besprinkled with small dark fossil seeds. The exact locality is the railroad cut just east of the town.