along the part of the gill to which the crab has approximated its abdomen and within easy reach of its claws. When feeding the crab moves, or rather scrapes, its claws over the gill, and by means of the hairy nature of its claws easily catches hold of the mucus-strings entangling the food and transfers them to the region of its mouth. The claw is now scraped over the region of the mouth, and the specially hairy mouth-parts of the crab, working in an opposite direction, comb off the strings of food and press them into the mouth. The claw of this crab is apparently specially modified to enable it to be flexed about the middle of its length for giving the unusual scope of action required for the scraping movements.

It is thus seen that the pea-crab is a parasite, and no advantage of its presence to the host has yet been detected, unless it be the occasional association of the palps with the crab, for in this case the crab would be relieving the host of the necessity for transporting and expelling undesirable food; on the other hand, the crab would appear to do no more harm to the mussel than to make it collect food faster or for a longer time than would be necessary in an abundant supply of food if the crab were not there.

There is thus good reason to believe that those allies of the pea-crab which are known to live in plankton-feeding animals—for example, other bivalves and Ascidians—will be found to feed in the same way as this crab.

In the search for these pea-crabs during the summer it was observed that berried females were frequently found alone in a mussel, and that males appeared to be scarce; the method of fertilisation, therefore, was not understood, and appeared to be worth investigating. It is well known that in this crab there is a marked sexual dimorphism, the males being small, very hairy, and, it may be added, very active, while the females are large, relatively smooth, and extremely passive. Moreover, tiny females have apparently never been described. There was thus the additional problem of interest of the whereabouts of the tiny females—if, indeed, tiny females should exist. The whole of the phenomena suggested protandry—a suggestion that was strengthened by my obtaining a tiny female form moulted from a minute supposed male crab with a carapace only 2.7 mm. wide. This tiny female form—now 3.3 mm. in diameter—however, was found to have enormous spermathecae crammed full of mature spiked sperm and only a trace of gonad, which was, however, obviously female. The moult of this specimen was now carefully examined, and found to possess the full number of abdominal appendages characteristic of the female, although otherwise not recognisable externally from a male.

Many other male-like tiny female specimens have been obtained, and also a series of moults which leave no doubt that the young male-like female attains the adult characters through a succession of moults. It is an interesting fact that all the larger females examined have been found to have their spermathecae always full of mature sperm. It would therefore appear that this pea-crab copulates precociously at an extremely early age before settling down to its later sedentary life, and, so far as my observations have gone, it would seem that no further meeting with a male is necessary, although males have been found in the autumn inside the same host as large females; a newly moulted female, however, appears to have no charm for a male. Sexual dimorphism in the species is thus seen to be accompanied by dimorphism of the females, and the change from the male-like form of the female to the adolescent young-bearing female form appears undoubtedly to depend upon, and to occur after, copulation. It would also appear that

copulation normally takes place inside the host, and that the males visit mussels in their search for females, since unwary male crabs have been found with their legs or bodies trapped by the mussel closing its shell before the crab could get inside. These crabs survive the rough treatment by reason of their extraordinarily strong carapace, and creep inside the mussel later when it must perforce relax and open its shell in order to breathe. The male-like female has a similarly hard carapace which prevents the animal being crushed to death if unluckily trapped by the mussel destined to become a host. Individual crabs have been found to be lacking a leg which might very well have been lost in this dangerous operation.

The life-story of this animal is probably not yet complete, since the tiny male-like female appears to possess a different sexual apparatus from the older forms, and a single male form has been found with a carapace closely resembling that of a female. It is hoped, therefore, to complete the investigations in the near future.

J. H. ORTON.

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November 10.

The Energy of Cyclones.

My objection to Mr. Deeley's suggestion (*NATURE*, December 16, p. 502) that cyclones are caused by an access of warmth in the stratosphere is that in that case the troposphere ought to bulge upwards over the cyclone, whereas, in fact, it bulges downwards. The inversion at the boundary renders it certain that the interchange of air between the troposphere and the stratosphere is very slow, and for the few days of the life of a cyclone we may, to get a clear idea, imagine a light but impermeable film to exist at the boundary. If a patch of air above the film were warmed by any means it would expand outwards and reduce the weight on the film, which should, in consequence, rise. If, on the other hand, the film were drawn downwards, the temperature of the air above it would rise, because each air-particle as it lost in height would come under an increased pressure, and be warmed adiabatically. If, then, the air is drawn outwards horizontally from a cyclone in the upper part of the troposphere, the conditions as to temperature and the position of the top of the troposphere that are known to prevail are readily explained.

The point mentioned by Sir Oliver Lodge in his letter in *NATURE* of November 25 has been, I think, put forward by von Besold and others, but Sir Oliver seems to have overlooked the result of the heat set free by the condensation of the vapour. Could a cubic metre of damp air be confined in an adiabatic but extensible balloon and the vapour be condensed by any means, the result would be an increase of volume, for the expansion due to the heat produced by the condensation would far more than balance the contraction due to loss of pressure. If, indeed, the heat-energy due to the latent heat of vapour all took the form of kinetic energy in the atmosphere, quite a trifling rainfall would suffice to produce over the same area the most violent cyclone ever recorded.

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The Mechanics of Solidity.

IN *NATURE* of November 18 last Mr. J. Innes pointed out that if a number of substances be arranged in order of increasing coefficient of linear expansion, then they are very nearly in a series of decreasing hardness, as shown by Brinell's, Moh's, or Auerbach's test, and he has, therefore, suggested, that it should be possible to obtain a fair

idea of the so-called mechanical properties of substances from an inspection of their more fundamental physical constants.

It seems highly probable that there is some simple relation between the many physical constants of substances, and, indeed, many formulæ connecting them have been put forward, viz.:

(1) Sutherland (*Phil. Mag.*, 1890 and 1891) proposed to find the characteristic frequency of the atoms of elements by the formula

$$\nu \propto \frac{\sqrt{\frac{T_s}{A}}}{\alpha T_s V^{\frac{1}{3}}},$$

where ν is the characteristic frequency of the atoms, T_s the melting point on the Absolute scale, A atomic weight, α mean coefficient of linear expansion between 0° Abs. and T_s° Abs., and V atomic volume $= A/\rho$, where ρ is the density.

(2) Einstein (*Ann. d. Physik*, 1911) has proposed

$$\nu = k \sqrt{\frac{V^{\frac{1}{3}}}{K \cdot A}},$$

where ν , V , and A have the same significance as above, K is the bulk modulus of elasticity of the body, and k a constant which Einstein's theory demands should have the value 2.8×10^7 , but for which the empirical value 3.3×10^7 seems to agree much better with observation.

(3) Debye (*Phys. Zeits.*, vol. xviii., p. 276, 1917, and *Ann. d. Physik*, vol. xiv., p. 789, 1912) asserted that ν is the frequency of vibration of those elements in a substance which determine the velocity of sound in it, and he has therefore calculated ν from E , and σ , where E is the Young's modulus of elasticity of the body and σ its Poisson's ratio.

If, now, the ν of Debye and that of Sutherland or Einstein are identical in their physical significance, we may write

$$\frac{\sqrt{\frac{T_s}{A}}}{\alpha T_s V^{\frac{1}{3}}} \propto \nu \propto \sqrt{\frac{V^{\frac{1}{3}}}{K \cdot A}} \propto F(E, \sigma),$$

where $F(E, \sigma)$ is Debye's function for the determination of ν in terms E and σ .

It is of interest to note that Debye's formula does not involve an empirical constant, and that the constant of proportionality in Sutherland's formula is $\sqrt{P}$, where P is Dulong and Petit's constant, i.e. the product of the specific heat and atomic weight of the element.

Other formulæ have been put forward by Planck, Lindemann, and Grüneisen, but it is not considered necessary to add them here.

For a discussion of the agreement of these formulæ with experimental results the reader is referred to *Phil. Mag.* for December, 1917, "Atomic Frequency and Atomic Number, Frequency Formulæ and Empirical Constants," by Dr. H. S. Allen.

Perhaps these formulæ are of the type of which Mr. Innes is in quest.

It will be observed that, in the foregoing, reference to the "hardness" value has been omitted; it is now proposed to justify this omission.

The moduli of elasticity, the ultimate strength, and the coefficients of expansion of a substance are, without doubt, the mathematical expression of certain body or bulk properties, and their magnitudes will depend on the state of equilibrium of the molecules within and throughout the body, as well as on those on the surface. On the other hand, the hardness of a substance was defined in *Engineering* for December 12, 1919, as "the resistance of a surface to deformation

by mechanical means," and is, therefore, a surface effect and not a bulk effect. If this is admitted, then the hardness number of a surface is probably closely related to its surface energy, and is, perhaps, a measure of a property analogous to the surface-tension property of a liquid. In this connection proposals put forward by Frenkel (*Phil. Mag.*, April, 1917) on "The Surface Electric Double Layer of Solid and Liquid Bodies" are of interest. In that paper it is maintained that every free surface is a parallel plate condenser the outer plate of which is negatively charged, and consists of electrons in the outer half of their orbits about their positive nuclei which form the positive plate. The charge per unit-area of this condenser is calculated from (1) the number of positive nuclei per unit of area of surface, (2) the number of electrons moving in orbits about one nucleus, and (3) the electronic charge.

The distance between the plates is obtained from the mean radius of orbit of the electrons of any one atom. Thus the energy per unit-area of surface can be calculated. Results obtained in this way were shown to be in agreement with the known surface energy and contact potential of the various elements considered.

It seems to the present writer that attempts to obtain formulæ connecting the mechanical constants of elements with their fundamental physical constants must be along this line if the hardness number is the main object of the search. Many difficulties, however, remain to be overcome, for it appears that the plasticity of a substance must have a much greater effect in determining the "Brinell hardness" than it does in determining the "Moh hardness" of any given substance.

V. T. SAUNDERS.

Royal Naval College, Dartmouth,
South Devon, November 29.

Needs of Polish Universities.

I AM travelling in East Galicia, and have only just seen Mr. H. G. Wells's remarks on the needs of scientific workers in Russia (see *NATURE* of November 11, p. 352). Using Mr. Wells as a text and applying it to Russia's neighbour, I should like to enter a plea for the Polish Universities of Krakow, Lwów (Lemberg), and Warsaw, which stand in the greatest possible need of American, English, and French scientific and technical literature. From the middle of 1914 to 1918 such literature was unobtainable, and since 1918 the rate of exchange—to-day 1500 Polish marks to 1l.—has placed it beyond the possibility of purchase by the three impoverished universities. For some months the Friends' Relief Mission has been making an effort at home to arouse practical interest in the problem, and recently we received some volumes of *NATURE*. These I took to the librarian of Warsaw University, who showed me over the library. The new English books could have been counted on the fingers of the two hands, and in the periodical-room not a single English periodical was being received, and only two in French. Similar conditions obtain in Krakow and Lwów, capitals of West and East Galicia, and two of the most important intellectual centres in reunited Poland.

CUTHBERT E. A. CLAYTON,

Sec. in the Field of the French Poland Unit.
Nadworna, East Galicia, November 24.

WE believe that the Anglo-American University Library for Central Europe exists to supply the need to which Mr. Clayton refers. The address of the secretary is London School of Economics (University of London), Clare Market, W.C.2.—ED. *NATURE*.