the foregoing experiments is not of the same brightness throughout its entire transverse section. Pass a white switch, or an ivory paper-cutter, rapidly across the beam, the impression of its section will linger on the retina. The section seems to float for a moment in the air as a luminous circle with a rim much brighter than its central portion. The core of the beam is thus seen to be enclosed by an intensely luminous sheath. An effect complementary to this is observed when the beam is intersected by the dark band from the platinum wire. The brighter the illumination, the greater must be the relative darkness consequent on the withdrawal of the light. Hence the cross section of the sheath surrounds the dark band as a darker ring.

The following four paragraphs, though printed nearly two months ago, have not been published hitherto. Might I say that whatever my opinion on the subject of "spontaneous generation" may be, I purposely abstain from expressing it here? That expression shall be given at the proper time. I desire now to show the practical value of the luminous beam as an investigator of the state of the air.

The question of "Spontaneous generation" is intimately connected with our present subject. On this point a kind of polar antagonism has long existed between different classes of investigators. Van Helmont gave a receipt for the manufacture of mice, and it was for ages firmly believed that the maggots in putrefying flesh were spontaneously produced. Redi, a member of the famous Academy del Cimento, destroyed this notion by proving that it was only necessary to protect the meat by a covering of gauze to prevent the reputed generation. In 1745 two very able men, Needham and Spallanzani, took opposite sides in the discussion, the forming affirming and the latter denying the fact of spontaneous generation. At the beginning of our own century, we find on the affirmative side Lamarck, Oken, and J. Müller; and on the negative Schwann, Schultze, and Ehrenberg. The chief representatives of the two opposing parties in our day are Pouchet and Pasteur.

The method of inquiry pursued in this discourse will, I think, help to clear the field of discussion. The experimenters do not seem to have been by any means fully aware of the character of the atmosphere in which they worked; for if this had been the case, some of the experiments recorded would never have been made. For example, to make the destruction of atmospheric germs doubly sure, M. Pouchet, the distinguished supporter of the doctrine of spontaneous generation, burnt hydrogen in air and collected the water produced by the combustion. Even in this water he afterwards found organisms. But supposing he had seen, as you have, the manner in which the air is clouded with floating matter, would he have concluded that the deportment of water which had been permitted to trickle through such air could have the least influence in deciding this great question? I think not. Here is a quantity of water produced and collected exactly as M. Pouchet produced and collected his. This water is perfectly clear in the common light; but in the condensed electric beam it is seen to be laden with particles, so thick-strewn and minute, as to produce a continuous cone of light. In passing through the air the water loaded itself with this matter, and hence became charged with incipient life.*

Let me now draw your attention to an experiment of Pasteur, which I believe perplexes some of the readers and admirers of that excellent investigator. Pasteur prepared twenty-one flasks, each containing a decoction of yeast, filtered and clear. He boiled the decoction, so as to destroy whatever germs it might contain, and while the space above the liquid was filled with pure steam he sealed his flasks with a blow-pipe. He opened ten of them in the deep, damp caves of the Paris Observatory, and eleven of them in the courtyard of the establishment. Of the former, one only showed signs of life subsequently. In nine out of the ten flasks no organisms of any kind were developed. In all the others organisms speedily appeared.

Now here is an experiment conducted in Paris, which shows that the air of one locality can develop life when the air of another locality cannot. Let us see whether we cannot here in London justify and throw light upon this experiment. I place this large flask in the beam, and you see the luminous track crossing it from side to side. The flask is filled with the air of this room, charged with its germs and its dust, and hence capable of illumination. But here is another similar flask, which cuts a clear gap out of the beam. It is filled with unfiltered air, and still no trace of the beam is visible. Why? By pure accident I stumbled on this flask in our apparatus room, and on inquiry learnt that it had been a short time previously taken out of one of the cellars below stairs. Other flasks were in the same cellar. I had three of them brought up to me; they were optically empty. The still air had deposited its dust, germs and all, and was itself practically free from suspended matter. You can now understand the impotence of the air of the Paris caves. The observation illustrates at once the influence of the germs and the accuracy of Pasteur.

The air of the cellar was afterwards examined by the electric lamp. Though less heavily charged than the air outside, it was by no means free from particles. This was to be expected, because the door of the cellar was frequently opened. The flasks themselves were the true tranquil chambers; on their sides the dust had been deposited, and to them it firmly clung. To prove this several flasks about ten inches in diameter were filled with common air, corked, and laid upon a table in the laboratory. After two days' quiet they were optically empty.

Nor is it necessary even to cork the flasks; for with their mouths open the air within them is scarcely disturbed, certainly not displaced. Two days' rest on one of the laboratory tables suffices to deposit the organic dust and to render the open flasks optically empty.

I have had a chamber erected with a view to experiments on this subject. The lower half is of wood, its upper half being enclosed by four glazed window-frames. The chamber tapers to a truncated cone at the top. It measures in plan 3 ft. by 2 ft. 6 in., and its height is 5 ft. 10 in. On the 6th of February this chamber was closed, and every crevice that could admit dust or cause displacement of the air was carefully pasted over with paper. The electric beam at first revealed the floating dust within the chamber as it did in the air of the laboratory. The chamber was examined almost daily; a perceptible diminution of the floating matter being noticed on each occasion. At the end of a week the chamber was optically empty, exhibiting no trace of matter competent to scatter the light. But where the beam entered, and where it quitted the chamber, the white circles stamped upon the interior surfaces of the glass showed what had become of the dust. It clung to those surfaces, and from them instead of from the air, the light was scattered. If the electric beam were sent through the air of the Paris Caves, the cause of its impotence as a generator of life would, I venture to predict, be revealed.

It cannot, I think, be doubted that the method of observation here pursued is destined to furnish useful control and guidance in researches of this nature.

Royal Institution, March 14 J. TYNDALL.

* In this case a polished silver basin was soldered to one end of a wide brass tube; the tube was filled with ice, the hydrogen flame was permitted to play upon the basin, and the water of condensation was then collected. Dr. Child also objects to Pouchet's experiment.

HEREDITARY GENIUS

Hereditary Genius, an Inquiry into its Laws and Consequences. By Francis Galton, F.R.S., &c. (Macmillan & Co.)

IN this book Mr. Galton proposes to show that a man's natural abilities are derived by inheritance, under exactly the same limitations as are the form and physical

features of the whole organic world. Many who read it without the care and attention it requires and deserves, will admit that it is ingenious, but declare that the question is incapable of proof. Such a verdict will, however, by no means do justice to Mr. Galton's argument, which we shall endeavour to set forth as succinctly as possible. He first discusses the classification of men by "reputation," and from a study of biographical dictionaries and obituaries for certain years taken at wide intervals, arrives at the conclusion that not more than 250 men in each million, or 1 in 4,000, can be termed "eminent"; and he shows what a small proportion that is, by the well-known fact that there are never so many as 4,000 stars visible to the naked eye at once, and that we feel it to be an extraordinary distinction in a star to be the brightest in the sky. These "eminent" men are the lowest class he deals with. The more illustrious names are as one in a million or one in many millions; but unless a man is so much above the average that there is only one like him in every 4,000, he is not admitted into the ranks of the eminent men on whom Mr. Galton founds his deductions.

He next discusses the classification of men according to their natural gifts. He shows first, that each man has a certain defined limit to his mental as well as to his physical powers, and that this limit is in most cases soon discovered and reached. He next shows the enormous difference that exists between mediocre and high class men, by the evidence of examination papers; the senior wrangler at Cambridge, for example, often getting thirty times as many marks as the lowest wrangler, who must himself be a man very far above the average. Statistics show, that the number of imbeciles and idiots are about the same per thousand as the eminent men. He then applies Quetelet's "law of deviation from an average" (which will be new to many of his readers), and deduces from it, that if men are divided into sixteen equal grades of ability, eight above and eight below the average, the six mediocre classes will comprise nineteen-twentieths of the whole; while it will be only the sixth, seventh, and eighth above the average who will rank as eminent and illustrious men, and form about one in four thousand of the adult male population.

The next chapter relates to the important question on which, indeed, the possibility of any solution of the problem depends, of whether "reputation" is a fair test of "ability." The subject is very ably discussed, and it is, I think, proved, that notwithstanding all the counteracting influences which may repress genius on one side, or give undue advantage to mediocrity on the other, the amount of ability requisite to make a man truly "eminent" will, in the great majority of cases, make itself felt, and obtain a just appreciation. But if this be the case, the question of whether "hereditary genius" exists is settled. For if it does not, then, the proportion of mediocre to eminent men being 4,000 to 1, we ought to find that only 1 in 4,000 of the relations of eminent men are themselves eminent. Every case of two brothers, or of father and son, being equally talented, becomes an extraordinary coincidence; and the mass of evidence adduced by Mr. Galton in the body of his work, proves that there are more than a hundred times as many relations of eminent men who are themselves eminent, than the average would require.

Turning now to the concluding chapters of the book, we meet with some of the most startling and suggestive ideas to be found in any modern work. The law of deviation from an average enables us to determine the general intellectual status of any nation, if we are able to estimate the ability of its most eminent men, and know approximately the amount of the population. We have these data in the case of ancient Attica; and Mr. Galton arrives at the conclusion, that the Athenians of the age of Pericles were, on the lowest possible estimate, nearly two whole grades of ability higher than we are. With all our boasted civilisation, and the vast social and scientific problems with which we have to grapple; with all our world-wide interests, our noble literature, and accumulated wealth; the intellectual status of the most civilised modern nation is actually lower than it was more than two thousand years ago! Well may Mr. Galton maintain that it is most essential to the well-being of future generations that the average standard of ability of the present time should be raised. Not less striking is his exposition of the effects of prudential restraints on marriage, on the general character of a nation. If one class of people, as a rule, marry early, and another class marry late in life, the former have a double advantage, both in having on the average larger families, and in producing more generations in each century. But, by the supposition, it is the imprudent who gain this advantage over the prudent; and Mr. Galton therefore denounces the doctrine of Malthus, that marriage should be delayed till a family can be supported, unless the rule could be imposed on all alike. I hardly think that this argument is sound, and I doubt if the imprudent who make early marriages do, in the long run, increase more rapidly than the prudent who marry late. Increase of population depends less upon the number of children born, than on those which reach manhood; and I believe that the prudent man who has acquired some wealth and wisdom before he marries, will give to the world more healthy men and women, than the ignorant and imprudent youth, who marries a girl as ignorant and imprudent as himself. It is also to be remembered that the men who marry late often marry young wives, and have as good a chance of large families as the imprudent.

Mr. Galton traces the long-continued darkness of the Middle Ages, and our present low intellectual and moral status, to the practice of celibacy and to religious persecution. Whenever men and women were possessed of gentle natures, that fitted them for deeds of charity, for literature, or for art, the social condition of the times was such that they had no refuge but in the bosom of the Church; and the Church exacted celibacy. Those gentle natures left no offspring; and thus was the race of our forefathers morally deteriorated. The Church acted as if she had aimed at selecting the rudest portion of the community for the parents of future generations; and the rules as to fellowships at our Universities are a relic of this barbarous custom, being bribes to men of exceptional ability not to marry. Religious persecution acted in the same way. The most fearless, truth-seeking, and intelligent were year by year incarcerated in dungeons or burned at the stake; so that, by this twofold selection, human nature was brutalised and demoralised, and we still feel its hateful effects in the long-continued antagonism to the essential requirements of an advancing civili-

sation. These concluding chapters stamp Mr. Galton as an original thinker, as well as a forcible and eloquent writer; and his book will take rank as an important and valuable addition to the science of human nature.

ALFRED R. WALLACE

SPECTRUM ANALYSIS

Die Spectral Analyse in ihrer Anwendung auf die Stoffe der Erde und die Natur der Himmelskörper. By Dr. H. Schellen, director der Realschule I.O., Cologne. (Brunswick, Westermann, 1870. London: Williams and Norgate.)

THIS book contains an accurate and luminous account of the recent discoveries in celestial chemistry and physics, and especially of the researches of our countrymen Huggins and Lockyer. As regards the completeness of that portion of the work bearing directly upon terrestrial chemistry, readers will, I fear, be disappointed. The first division of the book is devoted to a description of the means employed for the artificial evolution of light and heat of great intensity, beginning with combustions in oxygen, and ending with the electric-light. The second division is headed "The simple and compound spectra in their application to terrestrial matter;" whilst in the third and most important division Schellen considers the application of spectrum analysis to the heavenly bodies. The illustrations throughout the work are good, though many of them are not new, and are borrowed, without acknowledgment, from other books.

With respect to the physical constitution of the sun, it behoves us in this, the infancy of our knowledge, to be very careful in drawing positive conclusions. In the first place, there is no doubt that whilst Kirchhoff's original theory must undergo certain modifications, it will remain in its grand features as having first pointed out to us the true physical condition of the sun. The discovery of the chromosphere by Mr. Lockyer, in which, as a rule, only the bright hydrogen lines are seen, together with the yellow mysterious line of unknown origin, renders it difficult for us, especially if we accept Frankland and Lockyer's conclusions respecting the excessive tenuity of the upper chromospheric layers, to suppose that an atmosphere containing iron and the other 13 difficultly volatilisable metals can exist outside the chromosphere of sufficient density to effect such a powerful selective absorption as we see in the darkness of Fraunhofer's lines. Hence we should be inclined to agree with Lockyer that the absorption does not take place, as Kirchhoff suggested, in a far outlying layer of solar atmosphere, or in what we term the corona, but that the dark lines are produced within the chromosphere. But, on the other hand, upon what known physical basis are we entitled to assume that the higher lying portions of the solar atmosphere consist almost entirely of glowing hydrogen gas, whilst the lower lying layers contain the more easily condensible gases of the other 14 elements? The well-known laws of gaseous diffusion (to say nothing of the cyclones of vast magnitude and of enormous rapidity, which Lockyer has taught us are constantly mingling up the various layers of solar atmosphere), forbid us to suppose that the lighter hydrogen gas can ascend whilst the heavier metallic gases remain quietly below. If the components of the solar atmosphere are gaseous, they must be uniformly, or nearly uniformly, mixed. How then can we account for the constant presence in the chromosphere of the hydrogen lines, whereas the lines of the other constituents of the solar atmosphere are scarcely visible, except in special cases of the occasional projection of the vapours of magnesium and other metals, whilst the absorption is to occur in a lower gaseous layer, having a totally different composition?

Another point to be remembered is, that according to the law of exchanges the fact of the existence of absorption *necessitates* the existence of a lower temperature in the absorptive medium than in the *media* (either above or below) in which such absorption is not exhibited, and which may either give continuous or broken spectra, according to the physical and chemical nature of the incandescent bodies. How then can the iron and magnesium vapour exist nearer to the white-hot body of the sun than the hydrogen and yet possess a lower temperature? I am here forcibly reminded of the plausibility of a suggestion thrown out by Kirchhoff, in a conversation with me a few weeks ago, viz.: that the upper regions of the solar atmosphere may be constantly illumed by discharges of electricity; that the incandescent hydrogen may be heated not from below but from within its own mass, either by continuous flashes of lightning or constant auroral discharges; and, indeed, Zöllner has noticed the flashing out of certain bright points in the prominences, which may possibly be caused by solar lightning.

We must also bear in mind that the existence in the sun of a solid or liquid white-hot nucleus, as originally assumed, is not proved by the results of subsequent research; inasmuch as we learn from the recent researches of Frankland, Lockyer, and Wüllner (as indeed we may do from much older experiments), that incandescent gases under certain physical conditions emit white light and yield a continuous spectrum. So that spectrum analysis does not give us any *certain* information as to the physical state of that portion of the sun's body from which the main portion of light and heat proceeds.

H. E. ROSCOE

OUR BOOK SHELF

Essays on Physiological Subjects. By Gilbert W. Child, M.A., F.L.S., F.C.S. Second edition, with Additions; pp. 293. (London: Longmans, Green, and Co. 1869.)

THE present edition of Dr. Child's work is by no means a mere reprint of the last. It has undergone considerable modifications, chiefly in the form of additions, which will tend to make it more acceptable to a large class of readers. There is an almost entirely new essay on "Some Aspects of the Theory of Evolution," in which he endeavours to show how this theory is related to religious belief. He believes its proper meaning and tendency to have been much misunderstood; that far from being an "atheistical" conception, it is in reality only the scientific form of natural religion. The subject of "Physiological Experimentation on Animals" is also considered, whilst the last and longest essay, also new, is entitled "Physiological Psychology," in which he endeavours to make known to persons whose chief interest is in psychological rather than physiological science, all the chief points in the anatomy of the nervous system, necessary to be understood before he could explain, as he also attempts to do, the principal physiological conclusions which have been arrived at concerning brain action and mind.