who play the game and there is a chance of some bit of human value when the game is done.

In the promotion of human welfare through the advancement of science, men of science and the public have a common interest and may have a common share. I believe the American Association is especially adapted to furthering these common interests and could profitably undertake a study looking towards the development of a more effective programme that would serve the aims of man of science and layman alike.

In the United States as nowhere else patrons of art, literature and science have made investments in human good. The yields in benefits secured have varied much, but sometimes have been slight because the investments have been unsound. We trust that those of philanthropic intent who wish to promote human welfare through the methods of science will subject their donations to as careful checks as they would a financial investment in order to ensure a profitable yield in the way of scientific dividends. A newly established National Science Fund is in position to serve as a clearing house for advice on the probable scientific dividends which may be expected from investments in science.

Although we do, each of us, live in different and more or less separate worlds of our own, I trust we shall ultimately be able to acquire a social organization as orderly as the constellations of other worlds. In our fight for individuality and freedom in this War and in the peace to come, I do not despair. The experimental method has demonstrated we must use force without stint to show that freedom and political morality as well as personal honesty really pay. We still cherish the faith that the free search for truth by the methods of science has power to rebuild the world and will prevail.

SRINIVASA RAMANUJAN*

By PROF. E. H. NEVILLE
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SRINIVASA RAMANUJAN was a mathematician so great that his name transcends jealousies, the one superlatively great mathematician whom India has produced in the last thousand years. He was born at the village of Erode in Tanjore on December 22, 1887. His parents were Brahmins of high caste, but very poor, and without any means of direct access to influential people. Srinivasa's mathematical ability was soon recognized at the high school at the neighbouring town of Kumbakonam, which he entered at the age of seven. We are told with what delight the big sixth-form boys found at the bottom of the school a youngster who was ready to do all their hard sums for them, and with what mixed feelings he read in their books theorems which he had discovered for himself. In 1903, a few months before he left the high school with a scholarship to the Government college in the same town, there came into his hands a "Synopsis of Mathematics", a book containing the enunciations of some six thousand theorems, for the most part without proofs, and Ramanujan set to work systematically to establish the results. Geometry did not appeal to him, but

in algebra and calculus he found himself in a magic world, in which he lived for the next ten years. In proving one formula he discovered many others, and he began to compile a note-book, the first of the note-books which afterwards became famous.

Unfortunately, Ramanujan lived too completely in his new world. College regulations could secure his bodily presence at a lecture on history or physiology, but his mind was free, or, shall we say, was the slave of his genius. We know now that to describe one hour which Srinivasa Ramanujan spent on mathematics as mis-spent is absurd, but to the college authorities he was just a student who was neglecting flagrantly all but one of the subjects he was supposed to be studying. The penalty was inevitable: his scholarship was taken away, and he was told that he must repeat the year's course. So he ran away, and what he did and how he lived for the next few years is not on record. He returned to college for a short time, but failed to secure any academic qualifications.

Away from college, Ramanujan's wants were few, and for five years he was able to satisfy them without interrupting his investigations. But in 1909 he married, and needed definite employment. His unfortunate college record was a serious obstacle, and he obtained introductions from one to another of three Indian mathematicians, Ramaswami Aiyar at Tirukoilur, Seshu Aiyar in Madras, and Ramachandra Rao at Nellore, to whom in turn he produced his note-books as evidence that he was not the incorrigible idler his failures seemed to imply. Ramachandra Rao has given an account of Ramanujan's first interviews with him:

"Several years ago, a nephew of mine, perfectly innocent of mathematical knowledge, spoke to me: 'Uncle, I have a visitor who talks of mathematics. I do not understand him. Can you see if there is anything in his talk?' And in the plenitude of my mathematical wisdom, I condescended to permit Ramanujan to walk into my presence. A short, uncouth figure, stout, unshaved, not over-clean, with one conspicuous feature—shining eyes—walked in, with a frayed note-book under his arm. He was miserably poor. He had run away from Kumbakonam to get leisure in Madras to pursue his studies. He never craved for any distinction. He wanted leisure; in other words, simple food to be provided for him without exertion on his part, and that he should be allowed to dream on.

"He opened his note-book, and began to explain some of his discoveries. I saw quite at once that there was something out of the way, but my knowledge did not permit me to judge whether he talked sense or nonsense. Suspending judgment, I asked him to come over again, and he did. And then he had gauged my ignorance, and showed me some of his simpler results. I asked him what he wanted. He said he just wanted a pittance to live on so that he might pursue his researches. It is a matter of considerable pride to me that I was in some way useful to this remarkable genius in his earlier days."

Ramachandra Rao's interest took the most practical and generous form. He sent Ramanujan back to Madras so that he might work at the University there, and for a little more than a year he maintained him at his own expense. Many people, in India and in England, have been proud that they helped Ramanujan; of them all, perhaps his first benefactor deserves the highest praise.

* A talk broadcast in Hindustani in the Indian service on April 22, 1941.

Ramanujan, unwilling to be a burden for life, took in 1912 a clerkship under the Madras Port Trust, but Ramachandra Rao soon let the authorities of the Trust know what sort of a clerk they were employing, and thenceforward every assistance was given to Ramanujan. Francis Spring, the chairman of the Trust, made his post into a sinecure, and resolved to take the first opportunity of discussing the case with someone competent to appreciate Ramanujan's work. The opportunity came less than a year later, when an official visit was paid to Madras by Gilbert Walker, then director-general of observatories in India, a first-class mathematician trained in Cambridge. Walker's verdict, though he did not see Ramanujan and had only specimens of his work and not the note-books themselves to inspect, was unhesitating, and he wrote to the University authorities in Madras in the most emphatic terms: "The University would be justified in enabling S. Ramanujan for a few years at least to spend the whole of his time on mathematics, without any anxiety as to his livelihood." The words "at least" in this sentence are very remarkable. The University responded willingly, and with as little delay as was compatible with the fact that the situation was so far outside all precedent that explicit permission had to be secured from the Government of the Presidency, and on May 1, 1913, Srinivasa Ramanujan entered the Presidency College in Madras to practise as a virtue that single-minded devotion to mathematics which had been a vice in Kumbakonam nine years earlier.

Meanwhile, Ramanujan's name had become well known in Cambridge, the home of mathematics in England. G. H. Hardy, then a young lecturer at Trinity College and now the dominant figure among English mathematicians, who was destined to be closely associated with Ramanujan in the future, has sometimes said that Ramanujan was his discovery, but the truth is that Ramanujan chose Hardy. In a booklet dated 1910, Ramanujan found for the first time formulæ like some of his own, and acting on the advice of Seshu Aiyar, he wrote on January 16, 1913, a letter to the unknown author. No one who was in the mathematical circles in Cambridge at that time can forget the sensation caused by this letter. An obscure Indian clerk was appealing for advice because he was inexperienced, for help in the publication of his theorems because he was poor. "But only", he said, "if you are convinced that there is anything of value." Of the theorems sent without demonstrations, by this clerk of whom we had never heard, not one could have been set in the most advanced mathematical examination in the world. It must be confessed that the first suggestion was that the letter was a hoax, that the theorems must be familiar theorems skilfully disguised, but this explanation was soon abandoned, for there were some formulæ in the letter for which it certainly could not account. Of these Hardy has said, "They defeated me completely; I had never seen anything in the least like them before. A single look at them is enough to show that they could only be written down by a mathematician of the highest class. They must be true because, if they were not true, no one would have had the imagination to invent them." A great mathematician who has discovered formulæ of an entirely novel kind does not use them to mystify his friends.

Hardy answered the letter promptly, and Ramanujan knew that at last his intellectual solitude was at an end. His friends in India encouraged him and

supported him, but none of them had the knowledge to bring him the human satisfaction of being understood and appreciated; to Hardy he wrote, "I have found a friend in you who views my labours sympathetically."

But if Ramanujan was contented because he had escaped drudgery and loneliness, in Cambridge it was clear that his genius was still in danger of being wasted. It is not that any brain could do mightier work anywhere than Ramanujan's had performed at Kumbakonam in the carefree days before 1909, but that mathematics is cumulative and inevitable. If the architect of the Taj Mahal had designed a different tomb for Arjumand Banu, the most beautiful building in the world to-day would not have come into existence. But if Euclid had not discovered that the number of prime numbers is infinite, nevertheless that same theorem would have been discovered long ago by somebody else. Moreover, the world of mathematics is no richer if somebody who has not heard of the theorem discovers it to-day for himself. Of Ramanujan's work before 1913, Hardy has written that it was inevitable that a very large part of it should prove on examination to have been anticipated. "He had been carrying", he says, "an impossible handicap, a poor and solitary Hindu pitting his brains against the accumulated wisdom of Europe." It is the accumulation in Europe that we have to emphasize; Ramanujan was beginning every investigation at the point from which the European mathematicians had started 150 years before him, and not at the point which they had reached in 1913. Close contact with mathematicians of the highest class was an urgent necessity for him, but he did not yet know this, and when Hardy asked if he would go to Cambridge, Ramanujan declined, reluctant to lose caste, and deferring to opposition on the part of his parents, whose objections were religious, and of some of his friends, who saw in this invitation a mean attempt to transfer to the English University the glory that belonged to Madras.

I visited Madras myself in the opening weeks of 1914. After my first lecture Ramanujan was introduced. We sat down, and he turned the pages of a note-book. Two days later he turned the pages again, and after our third meeting he said, "Perhaps you would like to take it away with you." The astounding compliment took away my breath. The priceless volume had never before been out of his hands: no Indian could understand it, no Englishman was to be trusted with it. The truth was, of course, that the English were objects of suspicion not as individuals but as components of the governing machine; I came from outside the machine, and, for no other reason than that, I enjoyed an overwhelming advantage which was grossly unfair. Richard Littlehales, the professor of mathematics, in particular, had done and was to do far more for Ramanujan in Madras than I did.

Ramanujan's trust having been won so completely, I raised immediately the question of Cambridge, and found to my delight and surprise that Ramanujan needed no converting and that his parents' opposition had been withdrawn: in a vivid dream his mother had seen him surrounded by Europeans and heard the goddess Namagiri commanding her to stand no longer between her son and the fulfilment of his life's purpose. Lest he should be harassed presently by attempts to dissuade him, I addressed myself to the task of convincing his friends that the proposal was in Ramanujan's own interest. I wrote at once to

Hardy that the intangible obstacles had disappeared and that he must see that financial provision was made; I should try to obtain grants in Madras, but if I failed the money must somehow be found in England. I do not know what account I gave of Ramanujan and the note-books, but I made it abundantly clear that if Ramanujan was willing to come, financial difficulties simply must not be allowed to interfere. For a moment Hardy faltered. "Be careful what you promise", he wrote, and he forwarded a cautious memorandum of the "We-have-heard-of-these-untaught-geniuses-before" type, from the India Office in London. I claim no credit for ignoring this warning and laughing at Hardy's endorsement of it; I had seen the note-books and talked with Ramanujan, and Hardy had not. Moreover, while letters were travelling between Madras and London it was becoming likely that all the money wanted would be found in India. Littlehailes introduced me to everyone who carried weight in the University or in the civil administration; everywhere I talked of Ramanujan, explained as I have tried to do now the importance to him of a stay in Cambridge, and urged generosity. On January 28 I addressed to the University authorities a prophetic memorandum which began: "The discovery of the genius of S. Ramanujan of Madras promises to be the most interesting event of our time in the mathematical world", and ended: "I see no reason to doubt that his name will become one of the greatest in the history of mathematics, and the university and city of Madras will be proud to have assisted in his passage from obscurity to fame." Littlehailes drafted proposals in detail, and within a week the University, with the approval of the Government, had created a scholarship ample to maintain Ramanujan in Cambridge and his wife and mother in Kumbakonam. A few days later I left Madras.

It was in April 1914 that Ramanujan arrived in Cambridge, where he lived in my house until residential accommodation became available for him in July in Trinity. He felt the petty miseries of life in a strange civilization, the vegetables that were unpalatable because they were unfamiliar, the shoes that tormented feet that had been unconfined for twenty-six years, but he was a happy man, revelling in the mathematical society which he was entering, and idolized by the Indian students. The outbreak of war in the summer of that year affected profoundly his development. Most of the mathematicians whom it had been hoped that he would soon know disappeared from the University on war service of one kind or another; only Hardy remained, but Hardy had an unexpected amount of time at Ramanujan's disposal, and the two were constantly together. "I had to try to teach him", says Hardy, "and in a measure I succeeded, though obviously I learnt from him much more than he learnt from me." If Ramanujan's published papers are far narrower in scope than the note-books, if many of the ideas which had been born in India were neglected in England, it is because Hardy could guide Ramanujan rapidly and accompany him profitably only in regions of mathematics where he was himself at home. It was the War which separated Ramanujan from mathematicians with interests different from Hardy's but not alien to his own, and threw him into an association with Hardy so intimate that the two strands of their joint work cannot always be distinguished.

For three years, alone and in collaboration with Hardy, Ramanujan produced mathematical papers

of the highest quality in rapid succession. Then he fell a victim to tuberculosis. Immediate return to India was impossible, for the war-time voyage was risky and uncomfortable. After a year's constant attention in English nursing-homes, his health showed some improvement, and he enjoyed a brief period of brilliant invention. It was at this time that the two highest academic honours in England, which had never previously been conferred on an Indian, were conferred on Ramanujan. Early in 1919 he returned to Madras: travel was again easy, and the purpose of his sojourn in Cambridge had been accomplished, his family and his friends were waiting for him, his native land was impatient to do him honour. To everyone's dismay, the voyage or the return to a warm climate caused a relapse; for a year every care was lavished on him, but he died in Madras on April 26, 1920.

During his last year he worked slowly and in pain, but the work showed the old invincible originality. His last letter to Hardy, dated January 12, 1920, is singularly reminiscent of the fateful first letter, for it, too, contained a multitude of formulæ with only the obscurest hints of the theory from which they were derived. He was developing his last theory until he died, and it is a measure of his genius that fifteen years elapsed before this theory was understood and made public.

I must not end without making an attempt to describe the man himself. In figure he was a little below medium height, and stout until emaciated by disease; he had a big head, with long black hair brushed sideways above a high forehead; his face was square, he was clean shaven, and his complexion, never really dark, grew paler during his life in England; his ears were small, his nose broad, and always his shining eyes were the conspicuous feature that Ramachandra Rao observed in 1910. He walked stiffly, with head erect and toes out-turned; if he was not talking as he walked, his arms were held clear of the body, with hands open and palms downwards. But when he talked, whether he was walking or standing, sitting or lying down, his slender fingers were for ever alive, as eloquent as his countenance. He had a fund of stories, and such was his enjoyment in telling them that in his great days his own irrepressible laughter often swallowed the climax of his narrative. He loved a paradox, but I do not know of any that he invented; the paradoxical element in some of his own early work must have made him aware that the wildest nonsense of to-day may receive a logical interpretation to-morrow. He had serious interests outside mathematics, and was always ready to discuss politics or philosophy. Loss of caste was a price he was prepared to pay for coming to England, but he kept the price as low as he could by adhering as closely as circumstances permitted to the observances of his religion, and in particular by maintaining the strictest vegetarianism. "When I go back", he said to me once, "I shall never be asked to a funeral", and if he spoke with a sigh there was no sense of pollution mingled with his regret. In everyday life he had an instinctive perfection of manners that made him a delightful guest or companion. Success and fame left his natural simplicity quite untouched. To his friends he was devoted beyond measure, and he devised curiously personal ways of showing his gratitude and expressing his affection. The wonderful mathematician was indeed a lovable man.

Had Ramanujan not left India he might be alive

to-day, but he would have had always the sense of power and frustration, not of power and accomplishment. Death, too, was a frustration, but the life's purpose of which his mother dreamed was at least in part fulfilled, and it is better to be frustrated by unsought death than by life. So Srinivasa Ramamujan believed, for he told me just before he left England that he had never doubted that he did well to come.

DOMESTIC ENTOMOLOGY IN WAR-TIME

By DR. J. R. BUSVINE

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IT is a curious paradox that the cyclopean evil and stupidity of a world war stimulate intelligent co-operation within smaller spheres. Anyone who has read the pages of *NATURE* during the present War will be aware that men of science are giving serious thought to their organization, status and general relations with society. Progress has certainly been made in the allocation of research problems, collaboration between individuals and application of results. Unfortunately, much of what has been done lies under a war-time ban of secrecy, but anyone who knows something of the work of the Biological War Committee (see *NATURE* of February 28, pp. 227 and 234) is aware that this is so. It must, however, be admitted that the symposium on "Domestic Entomology" held by the Association of Applied Biologists on February 20 revealed a lack of co-ordination of this particular type of problem. The pest species discussed were not linked on anatomical, physiological or even ecological grounds but rather from considerations of the organization of advice and control. Domestic pest problems are constantly confronting sanitary inspectors and medical officers who usually pass them on to one research institute or another. It would seem desirable that the Ministry of Health should retain an entomologist to deal with such specialized problems.

Interest in some domestic pests waxes and wanes with external events. Thus, research on lice and scabies is stimulated by war and to some extent lapses in peace-time. The drive on slum clearance a few years ago attracted attention to that perpetuator of slum life, the bed-bug. In addition to *ad hoc* research, a long-range ecological study of the bug was initiated, the results of which are only recently available.

A sound film on "Malaria", produced by the Shell Oil Co., was shown. This film was designed to be shown to non-technical people to give a clear picture of the causes and control of the disease without being dull or too complex. It not only succeeded brilliantly in this but also included pictures of great interest to the professional entomologist (particularly those of the female mosquito laying eggs and the realistic animated diagrams).

Dr. Busvine described some recent applied research which seems to provide a safeguard against epidemics of lice and the terrible diseases associated with them. While people are all able to get regular changes of undergarments, the body louse is not likely to spread rapidly, and occasional cases of infestation can be dealt with by improvements on methods used in the War of 1914-18. At any time, however, unhygienic conditions may arise as a result of severe

bombing, invasion or other hazards of 'total' war which may favour the louse. If this pest becomes widespread it is exceedingly hard to eradicate, as was found in Flanders in the War of 1914-18 and in other subsequent epidemics. The difficulty, which consists in rapid reinfestation of deloused persons, can now be overcome by the use of lasting insecticides, applied in various ways, which 'proof' a person for a month after treatment. These methods, which have been thoroughly tested on verminous men, were illustrated by a short amateur film.

Dr. Busvine concluded by pointing out that the head louse, which is very much more common, is very closely allied to the body louse and may possibly be a disease vector. Similar lasting insecticides would be of value for this pest, applied as 'medicated' hair dressings.

The incidence of scabies in Great Britain is on the increase—a fact that cannot entirely be ascribed to war conditions because the increase started several years ago. Dr. K. Mellanby gave an account of some interesting recent research on the transmission of scabies. The experiments were made with the amicable collaboration of pacifist volunteers and scabetic soldiers.

Some controversy has arisen over the usual mode of transmission of the parasite; some holding that it is very largely indirect, others using that provoking word 'venereal'. It would be exceedingly difficult to discover what actually is the main mode of transmission, but Dr. Mellanby's experiments have certainly shown that indirect transmission is very much less efficient than even moderately intimate contact. Attempts to transmit the parasite on blankets or clothes were only successful one or two percentage of two or three hundred trials, whereas the mite was readily transferred between two men sleeping in the same bed, both wearing pyjamas.

Major Johnson reviewed the scabies problem from the statistical point of view. Although it is not possible to find all stages of the mite, the oviparous females can be counted with accuracy. Examination of scabetic cases revealed a remarkably low population compared with the numbers theoretically possible (estimating from the reproductive rate and length of the life cycle). Less than five live females were found on 50 per cent of the cases and only 5 per cent had more than sixty. Populations on individuals seldom rise sharply and sometimes decline to zero.

When we are living in the country we are often troubled by various families of biting flies. Dr. Kearns proposed thiocyanates as deterrents for our protection but warned us that what was effective for midges (*Ceratopogoninae*) might be quite inefficient for 'elegs' (*Tabanidae*). Some country houses are subject to periodic invasion by swarms of muscids and chloropids seeking to hibernate. They are very enterprising and persistent and it seems to be impossible to keep them out. The only remedy seems to be regular spraying by pyrethrum or thiocyanates in paraffin at the right time of year.

Dr. Kearns described a serious fly problem that has arisen in several bombed sites in our towns and cities. Wrecked food stores provided ideal breeding-grounds for houseflies and blowflies. Until it was possible to clear up the debris, a degree of control was achieved by weekly spraying with a tar oil emulsion and the use of an atomized spray for adults in neighbouring houses and shops.

Judging from inquiries at the Forest Products