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A Professor of Mathematics[1]

In 1998 Richard Borcherds was awarded the Fields Medal, the equivalent of the Nobel Prize in Mathematics and the highest accolade mathematicians can receive. (There is no Nobel Prize in mathematics, just as in many other fields.) This award was for his work on a topic so obscure that most mathematicians working in his former Cambridge University department are unable to understand what he is doing. His mathematical brilliance is unquestioned by other mathematicians, even if they cannot follow the specifics of his ideas.

Despite his facility with anything mathematical, Richard was puzzled by his sense of alienation from people. He found people to be complex, mysterious beings who were hard to comprehend because they did not conform to the laws of physics or math. Sure, he knew they had emotions and thoughts—in that sense, he wasn't completely mindblind—but he did not know which emotions and thoughts they were having.

The straightforward cases presented no difficulty for him. He could work out that someone might be sad if they got hurt or if they did not get what they wanted, and that they would be happy if they did get what they wanted. He could even appreciate that someone might be sad if they *thought* they were getting something that they did not want. Yet this is no great shakes, since even the average six-year-old child can work that out.[2]

The social world is far more sophisticated than this and moves at a tremendous speed. When people came round to his home, conversation and interaction would become confusing to him, even though it was just

the ordinary stuff of everyday chat between a group of friends. Faced with this sea of words and hidden meanings, of exchanges of glances and smiles, of innuendo and double-entendre, of bluff and deception, embarrassment and camouflaged flirtation, it was just all too much. It went over his head. People would tell him later what this or that joke had really meant, or why Michelle had walked off in a huff at that moment. But at the time it was simply beyond him to work out why she had taken offense and at what, or why everyone had suddenly laughed—except him.

In truth, he not only failed to understand all this social stuff but he also did not care much about it. When people came round to his home, he would initially sit with them, but at the earliest opportunity he would withdraw to the corner of the room, pick up his book, and soon lose himself in reading. Meeting him for the first time, you would be forgiven for thinking him rude, but those who knew him just accepted that that was Richard.

I met him in his Cambridge office. The room was relatively bare. He stared at me. After a few minutes it was clear he was not going to offer me a seat, so I said, "I'll sit down here, then," and picked a chair. Basic greetings or social niceties were clearly not part of his routine behavior. He perched several feet above me, on the corner of the desk, put his hands under his thighs, and started to rock back and forth gently. He would stare at the floor, then sporadically steal a glance at me, quickly returning his gaze to the carpet. The silence wasn't going to be broken by him, so I started the conversation.

I explained that I was interested in why he thought he might have Asperger Syndrome (AS), a comment he had made to a newspaper reporter in the *Guardian* that week.[3] He explained that he had been aware all of his life that he did not understand social relationships and had found out about AS on the Web. The descriptions seemed to fit him. He was, however, pleased that I had come to talk to him about it, to explore if this diagnosis was appropriate.

I thought the best way into this unusual situation was to tell him a bit more about AS. I told him that AS was thought by some people to be a form of high-functioning autism. That meant that such individuals had all the signs of autism (I gave him a brief sketch of this, along the lines of the previous chapter in this book), but with normal or even superior intelligence. He nodded. "That's me," he said.

This was a man of few words.

I went on to say that there were degrees of autism, and that you could have a little or a lot of it. He perked up at this point, since it was his view that he might only have it mildly, or that he might be right on the borderline. I told him that we had a way of measuring this now, so that we could, if he was interested, establish precisely where on the autistic spectrum he sat.

Measurement, quantification, statistical means, and distributions—he was hooked. He said that he would be happy to come to the Autism Research Centre in Cambridge and get tested. But that was for another day.

I was interested in his view of himself, but he thought that apart from his mathematical ability, he was in many ways quite ordinary. He could not have been more mistaken.

His own powers of self-reflection, and his judgment of what others might think of his behavior, were quite limited. He was a master of mathematical judgment, but had hardly left first base in relation to social judgment. I asked him, for example, if he thought any of his behavior was socially odd or unusual. Social oddness is the first key symptom of AS. He said that he couldn't think of anything in particular, though other people had told him that it was odd the way he ran down the streets everywhere, even when he wasn't in a hurry. I sat and listened. That did not seem too odd, since maybe he was a man who liked to get a lot done in his day and snatch a bit of exercise wherever possible. I asked him if there was anything else that he thought he did differently to others. "No," he said. What about communication, the second of the key symptoms of AS? Was there anything different about that? He could not think of anything, though admitted that he was not much of a conversationalist. From his perspective, talk was for finding out what you needed, and not much beyond that. I thought it was striking that he omitted to mention a major function of language, which is to communicate your thoughts and feelings to another person, and to find out how they might be feeling or thinking. I said as much, but he said that was not really of interest to him.

I asked him if he used email to chat to people, or if he had friends that he liked to spend time with or phone up, but he said that his use of email was restricted to work-related information exchange. He did not really have friends as such, though colleagues would sometimes come round to his apartment. He would often just leave them to chat to his wife, and withdraw into a book. He said that he was able to be with one other person, one to one,

for short periods. If he was in a group, he would get confused and withdraw. He said it had always been this way.

As for chatting on the telephone, he admitted that he avoided telephones. I raised an eyebrow. "Why?," I asked. He said that when he was younger, in his twenties and before, he had been afraid of telephones because he couldn't work out how to use them. It wasn't the mechanics of the handset itself. He could give you a lecture on the physics of telephones—how they worked electronically, what sound waves were, and so on. It was the social part that confused him. What you were supposed to say to the other person? When was it your turn to speak? When were you supposed to hang up? How were you to know how to finish or start a conversation? Or where conversation was supposed to go? He was even puzzled about why people phoned, sometimes.

He knew that sometimes other people thought he was rude, though he never intended to be. He had no idea how to work out what was the right or wrong thing to say in different situations. I tried to look as if I were not shocked. Here was a man who could fathom any mathematical problem you could throw at him, but who was unable to work out the basics of friendship or how to have a phone conversation. Was there ever a more dramatic example of dissociation between empathizing and systemizing?

For some years, my colleagues and I had been arguing for the "modularity" of empathizing, by which I mean the independence of empathizing from other processes, and here was Richard, the clearest instance of this that I could imagine.

In retrospect, it struck me that the telephone was a good test of communication skill. On a telephone one does not have access to a wider context, such as the other person's facial expression, to scaffold one's interpretation. Indeed, it occurred to me that many of the adults with AS I had come across had shown a clear abnormality in relation to telephones. Some would talk for far too long, not taking a break for ten minutes or more, even if the listener had not uttered an "Uh-huh" or an "I see" or an "Oh really?" Or they would talk far too minimally, just giving monosyllabic replies, or they would say things which were quite rude but which they did not intend as such. Richard showed a more extreme abnormality in relation to telephone conversation, in his case avoiding it altogether, because he was unable to even work out the basis principles of turn-taking, or what the other person might be interested in.

"So," he asked, "do I have Asperger Syndrome?"

I told him that a diagnosis was not something you could arrive at in a half-hour conversation, but that I would be willing to delve further, to verify if he did have the condition. I told him that I would need to gather information from people who had known him during his life, especially those who had known him in his childhood. He offered me the names of his math tutors who had known him during his undergraduate days, a family friend who had seen him a lot in his teens, and he said that I could visit his parents. I decided to take up this offer, since his parents would be in the best possible position to provide the critical information for a diagnosis. This is because the syndrome—for want of a better word—is developmental, not acquired; in other words, signs of the syndrome are typically present from early in childhood. There were certainly clues in his current adult life that his social behavior and understanding were out of keeping with that expected of a (then) thirty-eight-year-old, highly intelligent man. But it was important to discover whether his parents could provide independent corroboration of his impairment in empathizing alongside his talent for systemizing.

I emailed his father to arrange a visit.

Richard's Parents

Richard's father is a physicist at another university. He had wanted to be a mathematician himself, but had been advised to go into something more useful. He started in engineering, but eventually found himself drawn to physics, and then to the computational, mathematical side of physics. He gave me a picture of the family.

Richard has three brothers, two of whom are math teachers. I joked with Richard's father that it was more than a coincidence to have three sons who are mathematicians, but he did not particularly respond to humor. He simply commented that his own parents, Richard's grandparents, were also of a scientific bent, as were his wife's parents.

Richard's maternal grandmother had been a chemist. Richard's mother chimed in that Richard was similar to the members of both of their families, since he was very independent-minded and did not need people. Both of Richard's parents had moved from South Africa, and they had described

their own fathers as the kind of men who could have gone out in the bush for days or weeks alone, without any thought for their families back home, and without missing the company of other human beings. This streak of minimal social interest or involvement, together with talent in mathematics or scientific thinking, seemed to run through this remarkable family.

The bigger surprise came when I heard of Richard's third brother. Another mathematician, I wondered? It transpired that this third brother was quite disabled, and among the range of diagnoses he had was—autism. Since autism is strongly heritable, I was interested to hear that this too might run in the family. But I decided not to let myself be influenced by this fact, since we had not yet gathered a full history of Richard himself. His wider family was, of course, of indirect relevance but was not itself germane to establishing if a diagnosis for Richard was merited.

My questions to Richard's parents soon revealed a set of signs that seemed to fit, however. First, Richard's parents could not recall him having used the pointing gesture when he first started to communicate. This was the first clue, since the absence of the pointing gesture to share interest, at eighteen months of age, is an established risk factor for autism spectrum conditions.

I asked about his language development. Richard's parents recalled that he did not say his first words until he was two and a half years old. They did not think this was particularly late, and had not been concerned enough to seek speech therapy for him. They were aware, though, that he was one of the late developers in relation to language compared with other children in the community. In retrospect, having seen other toddlers more recently, they had realized that Richard had been different. I decided that although the onset of his single word vocabulary was late (the vast majority of children are producing single words by the age of two), the fact that he had some phrase speech by the age of three was significant since it indicated that he did *not* qualify for a diagnosis of language delay.[4]

He had been a quiet little boy, content to play alone. His parents could not recall him playing pretend games, except when he was a schoolboy when he became very interested in the game Battleships. He would play this for hours. The game Battleships does have a pretend dimension to it, since one has to treat the symbols on paper as if they were real battleships. But when I asked about it, the game that Richard played was more about spatial position and mathematical co-ordinates than anything else. Aside

from this, he was not particularly interested in dressing up, or in assuming pretend identities, and so on. Again, little interest in imaginative play, with all its creative variability, is another marker of autistic spectrum conditions in toddlerhood.

"Did he have any friends, as a child?" I asked.

"Sure," his mother replied. "He often had one friend round, to play Battleships. It was groups of children that he had no interest in."

That correlated with the picture of Richard as an adult, I thought.

Socially, he had not fitted in at school particularly well. He never stopped to think what others might be feeling. For example, his mother sat worrying one night when, as a teenager, he didn't come home until late. When he finally arrived home she said to him in an anxious state, "Oh Richard. Why didn't you phone me to let me know where you were?" To which he replied, "What for? *I* knew where I was."

It transpired that he had also had some minor obsessions too, such as being very fussy about his food and insisting on wearing the same clothes all the time. By the time he was a teenager, there was a clear obsession: chess. He spent all his free time playing chess or reading every chess book he could lay his hands on. He went out three or four nights a week to play chess tournaments and was in line for becoming a chess master. Then all of a sudden he gave chess up, as he realized that beyond a certain point it was only about competition, not fun.

His other major obsession during his school years was, of course, mathematics. His father said that Richard could have gone to Oxbridge at the age of twelve to read mathematics, but they did not push him in this, believing that it would be better for him to go at the right age. Nevertheless, he won national mathematics competitions and filled his room, and the house, with neatly decorated polyhedra that he had made himself. Each of these polyhedra was unique in terms of its size, shape, and number of protruding structures built on to its core, and his parents showed me some of the collection of these that they still hung from various ceilings around the house. The rest were stored in a glass bookcase at the school where one of Richard's brothers was teaching. There were hundreds of them. This certainly qualified as an unusual, strong, and narrow interest or obsession.

Richard's childhood was clearly consistent with Asperger Syndrome. I emailed Richard to make an appointment to talk through some of the im-

plications of this diagnosis. Diagnostic information is best imparted in person, one to one, in order to handle that person's reaction to the news sensitively. Richard said he was quite happy to have the diagnosis by email. Nevertheless, I went round to his office. He did not seem particularly surprised by the diagnosis, and said that when he was younger the diagnosis would have been useful but that now it did not really make much of a difference to his life.

He asked me and my colleague Sally Wheelwright if we wanted to join him for lunch, and we were pleased to take up the invitation. We walked to the local sandwich shop with two of his colleagues, his regular lunch companions. Richard ran ahead down the road, just as he said he ran everywhere. We followed the towpath along the river, chatting with his colleagues, Richard running ahead. He unexpectedly veered off the path, and I saw him striding across a field.

I started to follow him, thinking that this must be the route to the picnic spot, but his colleague said, "Oh, you don't have to follow him. We'll go along the path. Richard likes to go the muddy way." Sally and I looked at each other, somewhat surprised that Richard had just taken off alone when we had thought that we were his invited guests for lunch, but we then realized that this was all part of the condition. He had little awareness of what the other person might think, of what might confuse the other person or of what the other person might be expecting. I realized that his colleagues just accepted him for the way he is, which was wonderful.

The next week Richard came, as arranged, to our lab. He strode into my office, came right up to my computer and read what happened to be on the screen. In fact it was a confidential reference on a student, but that did not seem to cause Richard any embarrassment. He picked up some papers on my desk and put them down absent-mindedly. I said nothing, interested in his spontaneous behavior.

Sally and I decided it would be good to try to get some quantitative measures of his social understanding and degree of autistic traits, so we asked him to take the "Reading the Mind in the Eyes" Test. Richard scored 25 out of 36. People typically score on average 30 out of 36, so Richard's score was significantly lower than one would have expected. On the Empathy Quotient (EQ) he scored very low (12 out of 80), whereas the average score in the general population is 42 out of 80. On the

Friendship and Relationship Questionnaire (FQ) he scored very low (55 out of 135); most people score 80 out of 135. The FQ measures the extent to which an individual prefers intimate or empathic relationships, as opposed to relationships based around activities. On the Autism Spectrum Quotient (AQ), our questionnaire which measures autistic traits in adults with normal intelligence, he scored 32 out of 50. This is also typical of most people with AS. The average male without autism or AS scores 17 out of 50. He scored 19 out of 20 on the Folk Physics Test, which measures your ability to solve problems dealing with physical causality. He also had a very high score on the Systemizing Quotient (SQ). On this he scored 41 out of 80, which is well above the average score for the population (27 out of 80).

So these tests gave us quantitative evidence for his unusual profile—extremely low empathizing, extremely high systemizing, and a lot of autistic traits.

Richard Borcherds is an example of someone whose AS has not been an obstacle to achievement in his adult life; however, the diagnosis would have been valuable during his school years, as he was not fitting in socially and he admits that he would have found it beneficial to have had this recognized at that time. His talents in mathematics have resulted in his finding a niche where he can excel (to put it mildly), and where his social oddness is tolerated. The fact that he has also found a partner who accepts these qualities means that currently his AS traits do not cause any significant impairment in his functioning. He is thus an example of an adult who in a sense has adapted his AS to an environment where it is no longer a major, or indeed any, obstacle at all.

One might question whether Richard Borcherds really merits a diagnosis at all, given how well adapted he is. Certainly, he is not currently severe enough in his symptoms to warrant a diagnosis in adulthood, as his symptoms are not interfering with his daily functioning. In the jargon of the diagnostic criteria, he is not "suffering any impairment in his daily life." For example, he is not depressed (thankfully), unlike the majority of the patients we see in our clinic.

Fie is, fortunately, an outstanding example of a man who in a sense has outgrown his diagnosis. But it reminds us how important the environment is, since if you took the same Richard Borcherds and put him in a less un-

derstanding environment, in all likelihood his AS would cause him some degree of distress.

Innovation in Silicon Valley

Richard Borcherds' case raises the broader question of whether good systemizing skills (frequently accompanied by reduced empathizing skills) might carry with it the advantage of a talent for innovation. An example might be useful, in case this is becoming too abstract.

William Shockley started a research and development company in Palo Alto, California, in 1955. He had co-invented the transistor just a few years earlier, in 1947, at Bell Laboratories in New Jersey. What better proof of his systemizing talent. He is recognized by some as the man who made an early contribution to Silicon Valley, because he was able to select and attract very talented individuals from around the world. By the end of 1957, eight of Shockley's team had left to form their own company (Fairchild Semiconductor), the company that went on to pioneer the first integrated circuits on silicon (or "chips")- Before long, this technology had mushroomed around the whole area.

Shockley was clearly a high systemizer, and he selected his workers for their unique technical expertise (or systemizing skills). The fact that he was also a low empathizer can be inferred from his crude eugenic proposal of offering $1,000 per IQ point below 100 to individuals with such intelligence scores who volunteered to sterilize themselves.[5]

A number of media reports *(Wired,* Dec 2001) have suggested that the rate of autism and AS (both of which they offensively term "Geek Syndrome") may be unusually high in areas like Silicon Valley. The reports suggest that because such areas attract talented systemizers who then prosper and find a like-minded partner with whom to have children, this increases the risk that their offspring will have autism or AS. Against this view, it should be said that at present there is no evidence at all that the rate of autism and AS is higher in such high-tech environments, compared with other environments: high rates of 1 in 200 children are being reported in many areas, not just in silicon-rich ones. But this does not discount the possibility that there is a link between high

systemizing/low empathizing on the one hand, and a talent for innovation, or a risk of AS, on the other.

Physics

The description of high systemizers that I have outlined in this book strikes a chord among some academic physicists today. It is of interest that one study of the personalities of high-achieving physicists reported them to be less sociable than those in the general population.[6]

Helenka Przysiezniak is in that rare minority of female academic physicists—they number less than one in eight of all academic physicists. In 1998 she gave an interview with a reporter from the *Times Higher*, during which she discussed her male colleagues at CERN (European Organization for Nuclear Research):[7]

> They lack basic social skills and some do not take care of themselves . . . there is one characteristic that she says that all physicists have—herself included—and that is "arrogance." "You want to prove that something is right if you believe in it. That's just how it works when you're discussing the 'truth,'" she claims.

Przysiezniak suggests that a psychological analysis of the personalities that physics attracts would reveal that physicists are very focused, one-track-minded, obsessive even. They tend to be just as passionate about their other interests—many of the physicists at CERN are accomplished musicians and concerts are held there almost daily. The mountains and lakes that surround CERN offer the chance for skiing, mountaineering, and sailing, a chance that many of the physicists seize.

Skiing, mountaineering, and sailing—all require good systemizing skills, as does physics. Moreover, an arrogant assumption that you are right and everyone else is wrong suggests low empathizing skills in failing to recognize not only that others might have a valid point of view (there might be several ways of seeing a problem) but also that a dismissal of another's point of view might be hurtful to their feelings.

Paul Dirac

Paul Dirac (1902—84) is another interesting physicist to consider. He held the Lucasian Chair of Mathematics at Cambridge, the professorship that Isaac Newton had held and that is now held by Stephen Hawking. Between the ages of twenty-three and thirty-one, Dirac worked on his own interpretation of quantum mechanics, and formulated a quantum theory of the emission and absorption of radiation by atoms, the relativistic wave equation of the electron, the idea of anti-particles and even a theory of magnetic monopoles. By the age of thirty-one Dirac had been awarded the Nobel Prize.

The German physicist and biologist Walter Elsasser described Dirac as "a man ... of towering magnitude in one field, but with little interest or competence left for other human activities." Dirac himself confirmed this statement when he recalled his time as a Ph.D. student at Cambridge:

> [I] confined myself entirely to the scientific work, and continued at it pretty well day after day, except on Sundays when I relaxed and, if the weather was fine, I took a long solitary walk out in the country.

Furthermore, a Fellow at Cambridge described Dirac as someone who was "quite incapable of pretending to think anything that he did not really think."

Around 1950, Dirac was supervising Dennis Sciama's graduate studies at Cambridge. One day, Sciama burst in to Dirac's office, and said, "Professor Dirac, I've just thought of a way of relating the formation of stars to cosmological questions. Shall I tell you about it?" Dirac replied, "No." He did not seem to realize that his brevity could be thought rude. If someone in the audience of one of Dirac's lectures had not understood a point and asked Dirac to repeat it, Dirac would repeat it exactly. Dirac could not appreciate that he was being asked to rephrase his words differently in order to help the listener understand.

Paul Dirac's father was described as a rigid disciplinarian, who ran the household like a regiment and who was emotionally detached from his children. Paul later married Margit, a widow and the sister of a Hungarian physicist. He had two children with her, but he, too, remained detached from family life. Margit declared, "Paul, although not domineering like his father, kept himself too aloof from his children." The picture suggested by the Dirac family is one of extremely high systemizing abilities, with low empathizing.[8]

Isaac Newton and Albert Einstein

What have these two physicists got in common? Apart from being two of the greatest physicists that the world has seen, there is one other feature that they share: they had not only high systemizing skills but also rather low empathizing skills. Indeed, their social difficulties were probably severe enough to warrant a diagnosis of AS. Despite this, it didn't stop them achieving the highest levels in their chosen fields.[9]

An observer of Newton wrote that he

> always kept close to his studies, very rarely went a-visiting & had as few visiters ... I never knew him take any recreation or pastime, either in riding out to take the air, a-walking, bowling or any other exercise whatever, thinking all hours lost that were not spent in his studies.

We have an account of Einstein's childhood from his son Hans Albert:

> He was a very well-behaved child. He was shy, lonely and withdrawn from the world even then. He was even considered backward by his teachers. He told me that his teachers reported to his father that he was mentally slow, unsociable and adrift forever in his foolish dreams.

Einstein was described as "lonely and dreamy" as a child, with a difficulty in making friends. He was said to prefer "solitary and taxing" games, such as complex constructional play with blocks or making houses of cards up to fourteen storeys high. He would "softly repeat every sentence he uttered—a habit he continued until the age of seven." He was still not considered fluent in speech at the age of nine. He was also a loner: "I'm not much with people," he would say. "I do not socialize because social encounters would distract me from my work and I really only live for that, and it would shorten even further my very limited lifespan."

These two world-class physicists certainly showed many of the signs of AS, though whether they would have warranted a diagnosis is questionable, since they had found a niche in which they could blossom.

Michael Ventris: Arch Code-Breaker

A final character to mention briefly is Michael Ventris (1922—56), the man who cracked Linear B.[10] As a fourteen-year-old child he was exposed to this ancient hieroglyphic language that had been found by archaeologists, and for the next sixteen years he worked obsessively to make sense of what this ancient language might be. All he had were squiggles to go on, but Ventris, a talented linguist (he could speak English, French, German, Polish, Latin, Danish, and Greek, among others), was determined to work out the meanings of every squiggle, together with how they were pronounced and spoken.

His breakthrough came when he realized that Linear B was in fact Greek. He became the first person on the planet to be able to read and speak Linear B for 4000 years. His motivation was to crack the system—to systemize.

Ventris is described by his family and by colleagues as someone who was emotionally remote, a man who wanted to remain apart from people, and who became obsessed with cracking the code. He designed his home in Hampstead in London so that the children lived downstairs while he and his wife lived upstairs; he did not want his children to intrude into his adult space. Eventually he stopped talking to his wife, since he said that there was nothing left to talk about. His daughter said that he was never really interested in spending time with them."

These are people with the extreme male brain. Sometimes one finds them in academia (and typically in the "hard" sciences or mathematics), sometimes in practical pursuits (such as carpentry), or socially isolated occupations (working as a librarian or a gardener, for example). Sometimes they are the technical wizards in a company, or the innovator in a business. They are not invariably as distinguished as Richard Borcherds, but there is a red thread that runs through their lives that binds them all together: high systemizing and low empathizing.

Consider the words of Hans Asperger:

> To our own amazement, we have seen that autistic individuals, as long as they are intellectually intact, can almost always achieve professional success, usually in highly specialised academic professions, with a preference for abstract content. We found a large

> number of people whose mathematical ability determines their professions: mathematicians, technologists, industrial chemists, and high ranking civil servants ... A good professional attitude involves single-mindedness as well as a decision to give up a large number of other interests ... It seems that for success in science or art, a dash of autism is essential.

Some people with the extreme male brain end up with a diagnosis of AS because this profile leads to secondary problems, such as loneliness, unemployment, bullying, depression, and divorce. But happily, some never need a diagnosis because, despite having the same profile of strengths and difficulties, they find a niche for themselves among a group of people (or just one saint of a partner) who find their oddities somewhat charming and eccentric, and value their difference from others.