100 YEARS AGO

An automatic telephone exchange system, which does away with the necessity for the staff of skilled operators at present exquired at exchanges, is being introduced into this country from the United States by the Direct Telephone Exchange Syndicate. Instead of ringing up the central station, requesting the attendant to put him in communication with the person to whom he wishes to speak, and waiting while the required alterations are made on the switch-board, the subscriber to an exchange worked on the automatic plan is himself able to connect his telephone with that of any other subscriber without the intervention of a third person. Each subscriber has upon the front of his instrument a circular disc pivoted at the centre, and having one-half of its circumference inscribed with figures from to 0 to 9. If he wishes to communicate with another, he sets the disc so that the number of the other subscriber appears upon the dial, and he then finds his telephone in circuit with that of the person whose number he has indicated by his disc. When he has finished his conversation he simply hangs his receiver on its hook. Immediately, the switch which represents him at the exchange returns to its normal position, and communication is cut off.

From *Nature* 12 May 1898.

50 YEARS AGO

It is known that the spherical aberration of electron lenses sets a limit to the resolving power of electron microscopes at about 5 A. … The new microscopic principle described below offers a way around this difficulty, as it allows one to dispense altogether with electron objectives. Micrographs are obtained in a two-step process, by electronic analysis, followed by optical synthesis, as in Sir Lawrence Bragg's 'X-ray microscope'. But while the 'X-ray microscope' is applicable only in very special cases, where the phases are known beforehand, the new principle provides a complete record of amplitudes *and* phases in one diagram … It is a striking property of these diagrams that they constitute records of three-dimensional as well as of plane objects. One plane after another of extended objects can be observed in the microscope, just as if the object were really in position. – D. Gabor.

From *Nature* 15 May 1948.

Planet formation

Grainy pictures of new worlds

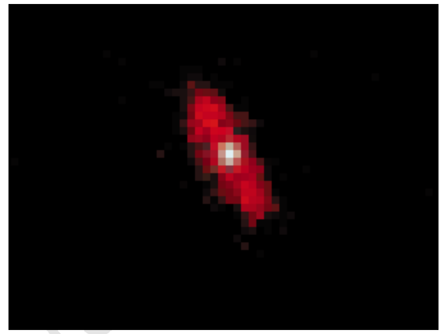
Vincent Mannings

We know that planetary bodies in our Solar System began by agglomeration of dust grains, rocks and mountain-sized asteroids. We also know that most of the work was done during the first 10 million years (Myr) after the Sun's birth, when the young star was encircled by an immense disk of grains and gas. But to go beyond this is not easy. Some 4.5 billion years after the main event, examination of our neighbouring worlds may never allow us to reconstruct fully how the Sun's early disk evolved into gaseous behemoths such as Jupiter and small rocky planets such as Earth. We must look elsewhere for better clues to our origins, and we find them in new studies of disks around three stars by Holland *et al.*[1], and of a disk surrounding the star HR4796A by Jura *et al.*[2], Jayawardhana *et al.*[3] and Koerner *et al.*[4].

Dust grains orbiting a star are bathed in the star's radiation field, and re-radiate this light at millimetre and infrared wavelengths. Holland *et al.*[1] used an array of millimetre-wave detectors to map the distribution of grains in disks around the nearby stars β Pictoris, Fomalhaut and Vega. β Pic is between 10 and 100 Myr old, Fomalhaut is around 200 Myr, and Vega is the oldest at 350 Myr. So with the possible exception of β Pic, each disk is now far beyond the main era of planet-building, and the grains are thought to be debris generated by collisions of asteroids formed earlier on.

All three debris disks have been known of[5] since the early 1980s, but only the edge-on disk around β Pic has been imaged before[6]. The new millimetre images[1] supply fresh information on each disk. In β Pic we again see the edge-on structure, but there is also a compact source about 700 AU from the star (1 AU is the mean separation of the Earth and the Sun). This object is to the southwest of β Pic. Perhaps it is some sort of disruption in the outer disk. Alternatively, it could be a distinct cloud of grains surrounding a low-mass companion star or sub-stellar object.

Holland *et al.* show that the 'disk' around Fomalhaut is toroidal, with an inner cavity of radius 30 AU. This is the radius of the orbit of Neptune, and it is also comparable to the radius of a cleared-out region of β Pic's disk seen[7] at mid-infrared wavelengths (0.01 mm, or 10 μm). Many of the grains formerly at distances less than 30 AU from Fomalhaut may have accumulated during an epoch in which a large population of asteroids, or 'planetesimals', was created within the very dense inner regions of Fomalhaut's primordial disk. These grains, now locked up inside the planetesimals, are no longer visible at millimetre wavelengths, and so we see a cavity in the debris disk. In the Sun's disk, planetesimals were the primary building blocks[8] of both terrestrial rocky planets and the cores of gas giants like Jupiter, raising the possibility that the cavity around Fomalhaut may also harbour one or more planets.



NASA/JPL/CALTECH

Figure 1 **An edge-on disk around the young star HR4796A. The star appears white in this composite infrared image. 13-μm emission (bluish-green) from warm grains is seen near to the star, and 21-μm emission (red) is mostly from a cool outer disk.**

The disk surrounding Vega is face-on to us, and there is a bright and elongated central region. This structure is centred roughly on the star and the northeast end is marginally brighter than its southwestern counterpart. What is it? The whole feature could be the result of gravitational perturbations of the grains by an unseen planet. Or maybe the northeastern enhancement is a compact object surrounded by a cloud of grains — a circumplanetary disk?

The star HR4796A is much younger, just 10 Myr old, or about the age at which the Sun's disk was well on its way to converting the bulk of its material into planets. Its environment is mid-way between the massive, pre-planetary gaseous disks orbiting some very young stars[9,10] and the tenuous dusty debris disks around the older stars just described. Jura *et al.*[2] show that a cloud of grains also encircles HR4796A, probably arranged in a disk with an inner cavity. The grains have a temperature of about 100 K, implying that they reside at a radius of 35 AU and beyond; the cavity is similar in size to the cleared-out regions around β Pic and Fomalhaut. This is confirmed by Jayawardhana *et al.*[3]: at 19 μm they see that the cloud is a disk oriented nearly edge-on, with an outer radius of at least 130 AU. Best of all, they see a direct hint of the inner cavity. Koerner *et al.*[4] present higher-resolution images at 13 and 21 μm (Fig. 1). Whereas the cavity is now seen more clearly at 21 μm, much of the 13-μm emission comes from within this inner 'hole'. Further, there is residual 21-μm emission from the same region. The ratio of the 13- and 21-μm excess fluxes from the inner region implies warm grains at a mean temperature of 250 K. That places them just 3 to 6 AU from the star.

So the HR4796A system appears to begin with a cool outer disk from about 35 to 130 AU. That corresponds to the location of the Kuiper Belt of comets at the outskirts of our own Solar System, as indeed do the locations of the disks around β Pic and Fomalhaut. The grains orbiting far from the young HR4796A may therefore be the precursors and/or debris of comets[2]. The space within 35 AU is not a void, but instead is home to at least a population of warm grains close to the star. We also find grains spread throughout our inner Solar System, primarily debris from collisions of asteroids, many of which reside between about 2 and 5 AU from the Sun. So the warm grains around HR4796A may be the signature of a population of asteroids existing at about the same relative position as most of the asteroids in our Solar System. More speculatively, the presence of asteroids may in turn signal the existence of planets. As for β Pic and maybe Fomalhaut, the very existence of a cavity within 35 AU of HR4796A may itself betray the presence of planets, freshly created from the dense material formerly comprising the inner primordial disk. These planets could then have completed the evacuation of the cavity by gravitationally clearing out their surroundings.

Planets are invoked at almost every turn. Are these four stars really accompanied by planetary families? Certainly there are strong indications that the disks are today being replenished by dust from disruptions of unseen larger bodies. Planets are probably in there, somewhere, but the authors of all these papers are rightly cautious, and we cannot yet make a secure leap from grains to young planetary systems. Although the disks may contain asteroids and grainy debris plus some mix of rocky, Earth-like planets and gaseous giants, they may instead simply be composed of asteroids, debris and nothing else. And what of our understanding of how planets are created? The most decisive way to explore such events is, of course, to observe directly young planets in the act of forming. That is for the future. In the meantime, the superb results described here will surely help us unravel the processes by which circumstellar disks evolve into planetary bodies. □

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Drug addiction

Cocaine and the serotonin saga

Francis J. White

Cocaine addiction remains a serious social problem, largely because we lack effective treatments for it. We know that, in the brain, the main molecular targets of cocaine are the transporter proteins that remove the neurotransmitters dopamine, noradrenaline and serotonin (5-hydroxytryptamine) from synapses after they have sent their messages to postsynaptic neurons. We also know that projection of the dopamine system to a region of the forebrain called the nucleus accumbens is mainly involved in the euphoric (rewarding) and psychostimulant effects of cocaine. Yet, paradoxically, cocaine has a higher affinity for the serotonin transporter than for the dopamine transporter.

On page 175 of this issue, Rocha *et al.*[1] have used mice that lack the serotonin-1B receptor to provide the first compelling evidence that a serotonin receptor is involved in the processes that underlie vulnerability to cocaine addiction. Although there had been suggestions that serotonin modulates cocaine-induced euphoria in a negative manner, the data were subject to different interpretations. Moreover, the diversity of serotonin receptors (at least 14), and the lack of ligands with necessary selectivity for the various receptors, made pharmacological analysis particularly difficult. The availability of gene 'knockout' mice now provides a means to circumvent these problems.

Rocha and colleagues determined the 'willingness' of serotonin-1B receptor knockout mice and their wild-type littermates to work for intravenous injections of cocaine. The mice were initially trained to self-administer cocaine by pressing a lever — each press resulted in a single shot of cocaine. Once the mice were trained, the authors 'upped the ante' by gradually increasing the number of lever presses required for drug delivery. They found that, as the workload increased, the knockout mice were much more willing to continue responding for cocaine, and, on average, they received twice as many injections as the wild-type mice.

Rocha *et al.* next tested whether, during repeated administration of cocaine, the lack of a serotonin-1B receptor would alter the normal process of behavioural sensitization. This term refers to a progressive increase in certain effects of psychostimulants as these drugs are repeatedly administered[2]. Although controversial, it has been argued that addiction results from changes in the brain dopamine system that may be responsible for 'wanting' drugs. In other words, 'wanting' — but not necessarily 'liking' — becomes sensitized[3].

The authors placed the mice in an open field, and locomotor activity (running) was detected by a video tracking system. The mice were also watched for the repetitive stereotypic behaviour, such as sniffing, rearing and head-weaving, that characterizes the stimulant effects of cocaine. During the initial exposure to cocaine the knockout mice ran about more than the wild-type mice, and, at relatively low doses of cocaine, stereotypic head-weaving was seen only in the knockout mice. After five daily injections of cocaine, wild-type mice were sensitized to both stereotypic behaviour and locomotor activity, whereas the knockout mice were sensitized only to the running response. These findings indicate that the serotonin-1B receptor null mutation had already produced a degree of sensitization to cocaine, because the knockout mice were more active initially and they showed stereotypic behaviour at what were sub-threshold doses in normal mice.

If the knockout mice were, in fact, pre-sensitized to cocaine, they might also show the neurochemical alterations that are known to be associated with cocaine sensitization. These include increased induction of a set of proteins that are related to the immediate early gene *c-fos*. Termed chronic Fos-related antigens (FRAs) because they are induced specifically by chronic treatment with cocaine and other drugs[4], they correspond to post-transcriptional modifications of ΔFosB[5], a truncated splice variant of FosB[6]. Chronic FRAs interact with products of another immediate early gene, *c-jun*, to form a DNA-binding complex known as activator protein-1 (AP-1) that regulates the transcription of target genes. Because chronic FRAs are expressed only with chronic cocaine treatment, and expression persists long after the cocaine has been withdrawn, this molecular adaptation is thought to be closely associated with the processes that underlie addiction to cocaine[7].