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Is schizophrenia the price that *Homo sapiens* pays for language?

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Abstract

The dichotomy between schizophrenia and manic-depressive illness is, as E. Kraepelin suspected, flawed; no unequivocal separation can be achieved. There are no categories of psychosis, but only continua of variation. However, the definition of nuclear symptoms by K. Schneider reveals the fundamental characteristics of the core syndrome—it is independent of the environment and constant in incidence across populations that have been separated for thousands of years. The associated genetic variation must be as old as *Homo sapiens* and represent a component of diversity that crosses the population as a whole. The fecundity disadvantage that accompanies the syndrome requires a balance in a substantial and universal advantage; this advantage, it is proposed, is the speciation characteristic of language; language and psychosis have a common evolutionary origin. Language, it is suggested, originated in a critical change on the sex chromosomes (the 'speciation event'—the genetic change that defined the species) occurring in East Africa between 100 and 250 thousand years ago that allowed the two hemispheres to develop with a degree of independence. Language can be understood as bi-hemispheric with one component function—a linear output sequence—confined to the dominant hemisphere—and a second—parallel distributed sampling occurring mainly in the non-dominant hemisphere. This mechanism provides an account of the generativity of language. The significance of nuclear symptoms is that these reflect a breakdown of bi-hemispheric coordination of language, perhaps specifically of the process of 'indexicalisation' (the distinction between 'I' and 'you') of self- versus other-generated references. Nuclear symptoms can be described as 'language at the end of its tether'; the phenomena and population characteristics of the nuclear syndrome of schizophrenia thus yield clues to the origin of the species. © 1997 Elsevier Science B.V.

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1. Is schizophrenia an entity?

There are serious doubts about the reality of 'schizophrenia' as a discrete category (Crow, 1986, 1995d; Boyle, 1990). The origin of the concept lies squarely in the distinction that E. Kraepelin (1919) drew between dementia praecox and manic-depressive insanity. On the one hand, Kraepelin argued, there are diseases in which mood change (depression or elation) is prominent, and psychotic symptoms (delusions and hallucinations) can be seen as congruent with and perhaps secondary to the mood change. These illnesses Kraepelin grouped together under the heading of manic-depressive insanity, from which a complete recovery can usually be expected. On the other hand, there are disease states in which the psychotic phenomena cannot be understood in this way. He grouped these illnesses, in which the outcome was not as

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good, together as dementia praecox and paraphrenia. Until recently, the separation of dementia praecox and manic-depressive insanity (the 'schizophrenic' and 'affective' groups of psychoses) has gone largely unchallenged. Indeed, it can be said to underpin most, if not all, modern psychiatric classifications, and exerts a profound influence on aetiological thinking. Schizophrenia, as dementia praecox following E. Bleuler (1950) has come to be called, and affective (manic-depressive) psychoses are generally regarded as distinct entities with separable patterns of symptoms, treatments and outcomes. By implication, they have separate aetiologies.

However, Kraepelin (1920) himself developed doubts. Thus, he wrote of

> the difficulties which prevent us from distinguishing reliably between manic-depressive insanity and dementia praecox. No experienced psychiatrist will deny there is an alarmingly large number of cases in which it seems impossible, in spite of the most careful observation, to make a firm diagnosis....it is becoming increasingly clear that we cannot distinguish satisfactorily between these two illnesses and this brings home the suspicion that our formulation of the problem may be incorrect.

It is undeniable that there are profound differences between different forms of psychotic illness. There is a relationship between form of illness and outcome—psychotic illnesses with affective features generally have a better outcome than those that lack such features, and this generalisation is Kraepelin's legacy. However, it is far from established that any categorical distinction can be drawn. 'Schizo-affective' illnesses (Kasanin, 1933) are common and, in the absence of principles by which they can be subclassified, they undermine the Kraepelinian dichotomy.

2. A continuum of psychotic illness

That schizophrenia is an elusive entity is demonstrated by a lack of agreement as to how it should be defined. Endicott et al. (1982) applied different sets of diagnostic criteria to a series of 46 patients admitted to the Psychiatric Institute in New York who met at least one of these definitions. By the most liberal criteria, 44 patients suffered from schizophrenia, but by the most restrictive, there were only six. Such findings engender scepticism regarding the existence of any such 'disease entity'. However, closer scrutiny reveals that the differences in this study between the sets of criteria are to a large extent accounted for by the extent to which different sets allocate patterns of illness to the categories of 'schizo-affective' and 'affective' psychosis. The more liberal criteria allocate more patients to the category of 'schizophrenia' and fewer to these diagnoses; the stricter criteria allocate the cases excluded from a diagnosis of 'schizophrenia' to the categories of 'schizo-affective' or even 'affective' psychosis. The category boundaries are arbitrary. The findings fit more readily with the notion that there exists a continuum (Crow, 1990c, 1994b, 1995b) that stretches from more 'understandable' manic-depressive psychoses at one end to the less understandable schizophrenic psychoses at the other.

What does the existence of such a continuum imply? While a categorical concept is compatible with an exogenous (environmental) causation, a continuum suggests rather that the disorder represents a component that is intrinsic to the individual, i.e. an extreme of variation in the normal population. Here, it will be argued that the symptoms constitute a clue to the genetic variation that epitomises the population of *Homo sapiens*, in the sense that the variation was generated in the transition from a precursor hominid, and that the relevant dimension relates directly to the function that characterises *Homo sapiens* as a species, that is language.

It was the particular contribution of K. Schneider (1957) to define a set of symptoms (those described as first rank or nuclear) that identifies the most characteristic core of the syndrome (Table 1). Nuclear symptoms (for example gedankenlautwerden, thought insertion and removal) are notable by their incomprehensibility. They represent some sort of loss of the boundary between the self and the outside world or, more specifically, other persons. Crucially, they constitute a pathology of the relationship between thought and language. While they fail to identify a category distinct from psychotic illnesses that lack such features, these symptoms define a threshold that tells us the meaning of the population distribution of psychosis.

Table 1
Some nuclear symptoms of schizophrenia

Symptom	Description	Putative non-dominant hemisphere origin
Experience that:		
feelings, actions are externally controlled	Delusions of control	Frontal
Hearing		
1. one's thoughts spoken aloud	Thought echo	Fronto-parieto-temporal
2. voices discussing one in the third person	Third-person hallucinations	
3. a commentary on one's actions	Running commentary	
Experience that thoughts are		
1. removed from one's head	Thought: withdrawal	Parieto-temporal
2. inserted into one's head	insertion	
3. broadcast to others	broadcast	

3. The World Health Organisation Ten Country Study of Incidence

As comprehensive an answer to the question of the incidence of nuclear schizophrenia as we have comes from the WHO Ten Country Study of Incidence (Jablensky et al., 1992). In each of ten centres distributed across populations as different as those of Japan, India, Northern Europe and Hawaii, these authors defined a catchment area and identified each of those facilities to which individuals experiencing psychotic symptoms for the first time might present. With standardised interviewing procedures, they were able to demonstrate good reliabilities between centres in eliciting symptoms and reaching a diagnosis (see Fig. 1).

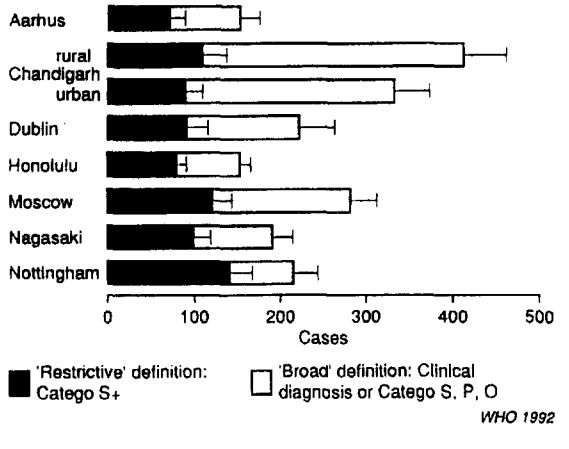

Fig. 1. Incidence of schizophrenia in seven centres according to broad and restrictive definitions in the WHO Ten Country Study (Jablensky et al., 1992).

The main finding constrains our concepts of origins. Whereas with a 'broad' definition (that included diagnoses allocated by the hospital clinicians as well as those of the researchers adopting liberal criteria), there were significant differences between centres in incidence, when the criteria were more narrowly defined, specifically by the presence of the nuclear or first rank features, the differences between centres became less and, in this comparison, were not significant. The meaning becomes clearer when one considers psychosis as an entity that can be defined by differing (broader or narrower) diagnostic thresholds. If there were real differences in incidence between populations, as the criteria were drawn more restrictively, one would expect the differences in incidence to become greater. However, this is not what is seen. In fact they become less (and the variance is reduced). This finding is consistent only with a second interpretation—that incidence is constant across populations, and that the differences with broad diagnostic criteria arise from differences in the levels at which the threshold is drawn (Fig. 2).

Schizophrenia, it seems, is constant across populations that differ widely in geographic, climatic, industrial and social environment, and the utility of first rank symptoms has been to demonstrate this fact. These symptoms define a level of severity or non-understandibility at which it is highly likely that an individual who experiences them for the first time will present to a psychiatric or related service, and thus will be enumerated as in the WHO study.

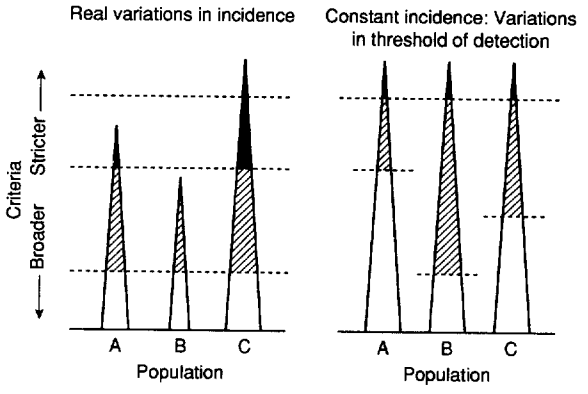

Fig. 2. Two possible interpretations of the findings of the WHO Ten Country study.

The conclusion is challenging. If schizophrenia is independent of the environment, it differs from common physical diseases such as coronary artery disease, diabetes and arthritis. These represent an interaction between genetic and environmental aetiological factors in a way that schizophrenia does not. Schizophrenia, it seems, is a characteristic of human populations. It is a disease (perhaps the disease) of humanity.

4. How old is the schizophrenia mutation?

If the variation underlying these psychological phenomena is genetic, one can ask 'how old is the schizophrenia mutation?' Either the mutation (i.e. genetic variation) or the mechanism that gives rise to it must have preceded the separation of the populations in which it is now present. Given that the Japanese, Indian and North European populations have been separated for thousands (probably at least 10 000) years, the 'mutation' is clearly old. When one considers in addition that schizophrenia with essentially the same features is present in the Australian aboriginal population that separated from the rest of modern *Homo sapiens* at least 50 000 years ago (Mowry et al., 1994), it is apparent that the variation must indeed be ancient—in fact, it must have preceded or been coincident with the origin of modern *Homo sapiens*, an event dated [on the basis of mitochondrial DNA evidence (Stoneking et al., 1992)] to between 137 000 and 250 000 years ago that occurred somewhere in East Africa (Stringer and McKie, 1996) (see Fig. 3).

The genetic change that preceded the diaspora of modern *Homo sapiens* can be regarded as the 'speciation event', the event that enabled this species to expand in population size to occupy a range of ecological niches in a way that no previous primate species had done, to shape the environment to its own advantage and to threaten the survival of many other organisms. It must presumably relate to the species characteristic of language.

A second question can be asked: who (apart from sufferers themselves) carries the schizophrenia predisposition? This question is relevant to genetic linkage studies (that attempt to locate a gene or genes) but has also been asked in a eugenic context by those who have thought that it might be possible to eliminate this predisposition from the population. As the forerunner to the Nazi policy of genocide during the Second World War, this view has an unfortunate historical precedent (Meyer-Lindenberg, 1991).

The WHO study casts light on this issue. It cannot be that there is a fraction of the population that carries a gene that is absent from the remainder because if such a fraction existed, there is no reason why it should remain constant in populations that have been separate for tens of thousands of years. Variation between populations, either as a result of differential selection or genetic drift, would be expected. One must conclude that the variation of which predisposition to schizophrenia forms a part is not confined to a subfraction—it must cross the population as a whole.

Alongside population distribution as a peculiar and unexplained characteristic is age of onset. Onsets of psychosis occur (a mean 2–3 years earlier in males than females) throughout the reproductive phase of life (Penrose, 1991). As this is also the healthiest phase, in which the expectation of physical disease is lowest, these facts again draw attention to the singularity of psychosis. Given that the illness is associated with a procreative disadvantage [sufferers are less likely than the population in general to have children (MacSorley, 1964; Vogel, 1979) perhaps by a factor of 50%] this fact points a finger at the central paradox—if the disease is

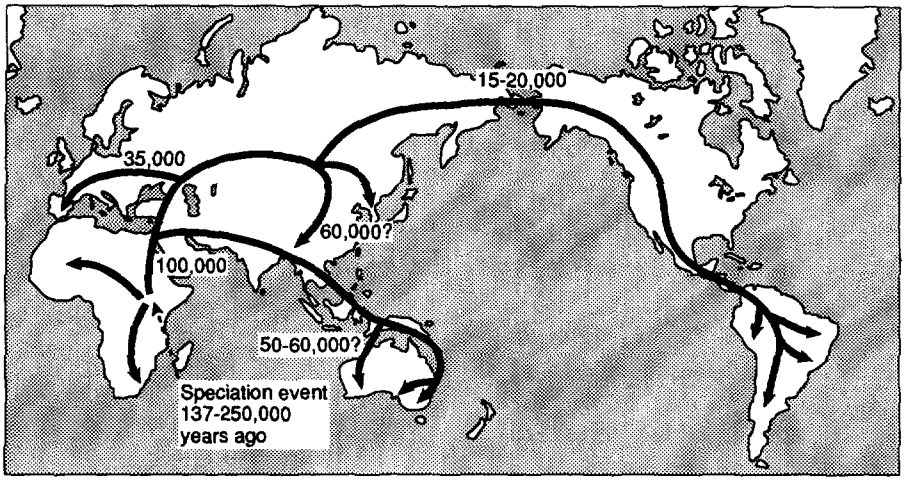

Fig. 3. The diaspora of modern *Homo sapiens* [modified from Stringer and McKie (1996)].

genetic in origin, why are these genes not selected out of the population?

5. Language and psychosis: common evolutionary origins

A Darwinian theory (a theory of the origins of the genetic variation and its associated advantage) is required (Crow, 1995e). To what function might such a variation relate? What advantage balances the disadvantage associated with schizophrenia? Clearly, the advantage is not present in sufferers themselves, nor from the arguments given above can it be confined to the first degree relatives. If the predisposition to schizophrenia is a part of variation that crosses the population as a whole, and if it can be traced back to the origin of modern *Homo sapiens*, the conclusion is difficult to resist that this genetic variation is directly associated with the function that characterises the species, i.e. language (Crow, 1995a, 1996b).

As communication, language has characteristics that distinguish it from precursor primate systems. de Saussure (1916) emphasised that the relation between the sign (word) and what it refers to is arbitrary. Words signify what, by usage within the language-speaking community it has been established, they shall signify; they are learned and can be multiplied. Vervet monkeys have a system that communicates 'eagle', 'leopard' or 'snake' to other vervet monkeys, but the signs that they use are fixed (Cheney and Seyfarth, 1990). In human language, as Chomsky (1965) has pointed out, the number of possible sentences is effectively infinite, but each properly formed sentence can be recognised as such by a competent speaker of that language at first hearing. The capacity for language thus is the identifying feature of *Homo sapiens*, but it is one for which there is limited archeological documentation (Bickerton, 1995). Evidence for representational ability, as shown by rock art, goes back no more than 50 000 years (Noble and Davidson, 1996). Like the complexity of language itself, the capacity to represent appears to be intrinsic to *Homo sapiens*, and relatively constant across populations. The two abilities may reflect different aspects of a single genetic change that underlies the communicative potential of the human brain. Language has its origin in the change (the 'speciation event') that gave rise to modern *Homo sapiens*, an event that introduced an innovation in the functional organization of the brain.

6. Hemispheric lateralisation and the genetics of asymmetry

The salient fact about the neural basis of language is that it is lateralised. The capacity for

language apparently has evolved by a process of increasing hemispheric specialisation, cerebral control ('dominance') for language being localised in one (most often the left) hemisphere. Such specialisation is accompanied by a preference to use the right hand for tasks requiring fine motor skill. This change may have been presaged in *Homo erectus* or even in *Homo habilis* (Steele, 1997), but directional asymmetry for motor skill certainly is greater in man than other primates. It may be a species characteristic, but one for which variation within the population is maintained (McManus, 1991; Perelle and Ehrman, 1994): somewhere between 6 and 12% (depending upon the criterion) of all populations that have been studied has a preference for the use of the left hand.

Transmission of handedness (an index of asymmetry in the brain) within families can be accounted for by a single additive gene (the 'right shift factor') that biases the left hemisphere and right hand towards dominance over their contralateral partners (Annett, 1985). As a theory of the transmission of handedness within families, Annett's has points in common (e.g. the postulate of a single gene combined with a random influence) with that of McManus (1985). More controversially, Annett has argued that the different genotypes at the putative 'right shift' locus (estimated from their position on a continuum of relative hand skill) are associated with different cognitive abilities, specifically that heterozygotes (±) for the right shift factor are at an advantage with respect to homozygotes (−/− and +/+). The genetic variation at this locus would thus be a case of a 'balanced polymorphism', in which heterozygotes have a survival advantage over homozygotes, a situation that can maintain variation in the population against selective pressure. Evidence to support this view comes from a the UK National Child Development cohort. On a test of hand skill at the age of 11 years, those who were strongly lateralised in either direction were at a disadvantage compared to those who were less strongly lateralised, in agreement with Annett's theory, but those who were most disadvantaged (on verbal; and non-verbal ability as well as mathematics and reading skills) were those who were closest to the point of equal hand skill, or the point of 'hemispheric indecision' (Crow et al., 1996).

Dominance for language and handedness is reflected in anatomical asymmetry in the brain. In most individuals, the width of the brain is greater on the right in the frontal region and on the left in the occipito-parietal region, and the lateral (Sylvian) fissure (that divides the temporal from the parietal lobes) is longer on the left (Witelson and Kigar, 1988). These asymmetries are less in those who are left-handed or ambidextrous (Bear et al., 1986; Foundas et al., 1995). The variation could represent modulation of the influence of a single growth factor (see Fig. 4).

Sex differences in asymmetry are present. Males are more likely to be left-handed—12 vs. 10.5% (McManus, 1991)—a difference that was present in the UK National Child Development Sample—and have a greater mean asymmetry in the brain than females (Bear et al., 1986). These differences presumably are related (see below) to the small, but well-established, mean difference in the distribution of intellectual abilities—with substantial overlap between the sexes females have a greater verbal fluency and males have a greater spatial ability (Maccoby and Jacklin, 1975; McGlone, 1980; Halpern, 1992).

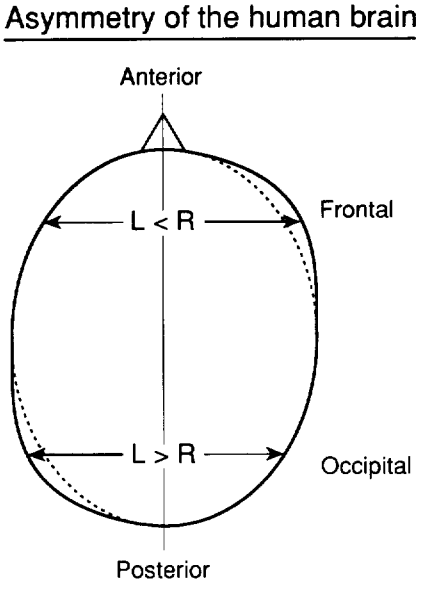

Fig. 4. Width asymmetries in the human brain.

7. The hypothesis of an X–Y homologous gene

The origin of such sex differences is of considerable interest. I have suggested (Crow, 1993, 1994a, 1995c) that they reflect the operation of an X and Y-linked gene, that is a gene that is represented in homologous form on both X and Y chromosomes. The simplest hypothesis is that this gene itself is the asymmetry determinant, i.e. Annett's right shift factor. The evidence is

(1) that individuals with sex chromosome aneuploidies have relative hemispheric impairments or delays. Individuals who lack an X (XO, Turner's syndrome) have right-hemisphere (non-verbal) deficits, whereas individuals with an extra X (XXY = Klinefelter's, and XXX syndromes) have left-hemisphere (verbal) deficits. This suggests that there is an asymmetry determinant on the X chromosome, but the fact that males (XY) do not have deficits comparable to those present in Turner's syndrome even though they have only one X indicates that there must be a gene of comparable effect on the Y chromosome (Crow, 1989, 1993, 1994a, 1995e) (see Fig. 5). It should be noted that Geschwind and Galaburda's hypothesis (Geschwind and Galaburda, 1985) that sex differences in cerebral asymmetry are secondary to a hormonal influence is ruled out by the similarity of the hemispheric deficits in XXY (male) and XXX (female) individuals.

(2) that within families there is an association between sex and handedness, siblings of the same sex being more likely than individuals of opposite sex to be of the same handedness (Corballis et al., 1996). The effect is small (being significant at the 0.02 level in a sample of 15 000 sibships), but its magnitude is as expected from the combination of random and right shift effects in Annett's theory.

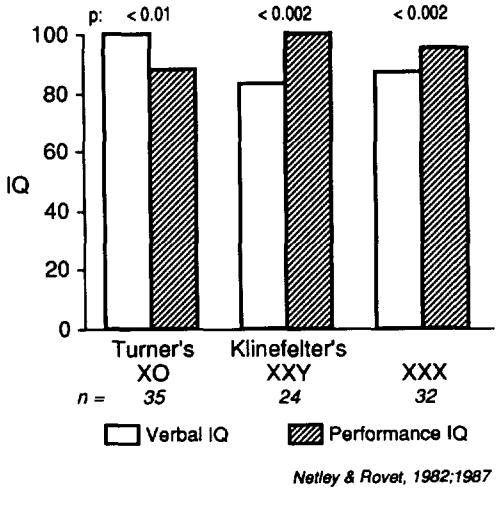

Fig. 5. Neuropsychological impairments associated with sex chromosome aneuploidies [from Crow (1993)].

X–Y homologous genes constitute a recently recognised class (Lambson et al., 1992). It includes genes within the pseudo-autosomal (exchange) regions at the telomeres of the short and long arms of the X and Y chromosomes, as well as a small but increasing number of genes outside this region. The gene copies on the X chromosome are not subject to inactivation, a protection that ensures gene dosage equivalence between the sexes. Whereas for genes within the pseudo-autosomal region (where there is recombination between X and Y chromosomes in male meiosis), strict sequence homology between the copy on the X and that on the Y will be expected, outside this region, recombination does not take place, and divergence between X and Y copies will occur. Such divergence, whether in a protein-coding or control sequence, could account for a sexual dimorphism. In evolutionary terms, these genes will also be subject to the force of sexual selection (Crow, 1996a).

8. The origins of generativity

What is most characteristic about language is its generativity—the capacity for recombination that distinguishes the communicative ability of humans from that of other organisms (Chomsky, 1965; Bickerton, 1990; Corballis, 1991; Maynard-Smith and Szathmary, 1995) and that made Darwin's thesis (Darwin, 1871) of continuity in The Descent of Man so controversial. How could an apparently gradual process account for what seems to be an entirely novel capability?

The answer must lie in the allocation of function

to one or other of the two hemispheres. It is this potential that appears either to be restricted to, or at least to have greatly developed in, the hominid progression. Whereas previously, the two hemispheres were closely matched in their functions and these were related in a parallel and topographical manner to their respective motor and sensory fields, in *Homo sapiens*, there has been a radical departure [see Annett (1985); McManus (1991); Corballis (1991) and Steele (1997) for discussions of this discontinuity].

Why was the potential for a degree of functional independence of the hemispheres so important? Following Dax (1865) and Broca (1861), it is often stated that language is localised in the left or dominant hemisphere with the implication that something else is localised in the non-dominant hemisphere, but this clearly cannot be the case. What other function could this be? Cook (1986) asks:

> What is the right hemisphere doing while the left hemisphere is busy with the chores of linguistic communication...serious consideration of the nature of hemispheric interactions via the forebrain commissures demand that we ask what one hemisphere is doing simultaneously with the 'dominant' functions of the other hemisphere. If the cerebral hemispheres are indeed as 'yoked' to one another as the massive commissural connections suggest, then the activity on one side must somehow result in complementary activity (in an unknown, but physiologically precise way) on the other side.

If language is the faculty by which *Homo sapiens* has speciated and hemispheric specialisation is the process by which this has taken place, it follows that what brain modifications there have been in *Homo sapiens* are attributable to this fact. The increased interconnectivity of diverse cortical areas relates to this core function; specific components of language must be located in each hemisphere. Language, therefore, is a whole brain function; it must be bi-hemispheric. The key to the interaction between the hemispheres rests in the mysterious process of the establishment of 'dominance'. What component is present in the dominant hemisphere, and why does it have to be so segregated? What complementary component is present in the non-dominant hemisphere, and how is it tapped from the other side?

Answers to these questions, it is suggested, must lie in the relation between temporal and spatial aspects of language, for example in the 'spatialisation of form' hypothesis (Lakoff, 1987; Deane, 1993), the concept that language is, in part, spatial as well as temporal. Sign language provides clues to the neural basis; in particular, its transmission through visual and motor modalities undermines any claim for phonological and acoustic primacy, and therefore for any overwhelming significance for Wernicke's area in speech perception. Armstrong et al. (1995) suggest that this fact shifts the focus from the fine temporal organisation of the acoustic modality to the spatial and action-orientated nature of language. Sentence structure, they suggest, can be understood as gestures relating to the body and to external space. Other authors (e.g. Jackendorff, 1996; Bierwisch, 1996; Johnson-Laird, 1996) have considered how some semantic and morphologic relations can be understood in terms of spatial constructs. The question arises whether spatial organisation is in some sense fundamental to syntax. This has at times been suggested—see, for example, Anderson (1971), Lyons (1977, pp. 718–724), Lyons (1995, Ch. 10), Jackendorff and Landau (1992) and Deane (1993). The specific hypothesis being developed here is that there are both temporal and spatial aspects to language, that the two are segregated (in the two hemispheres), and that the interaction between them is central to the mode of operation of the human brain.

Why the output sequence is restricted to one hemisphere can be explained by the physiology of callosal transmission, specifically from limits to the ways in which the two hemispheres can interact. The time delay of approximately 25 ms for transmission through the corpus callosum precludes multiple inter-hemispheric passes in the course of single actions (Ringo et al., 1994):

> these temporal limits will be avoided if the neural apparatus necessary to perform each high-resolution, time critical task is gathered in one hemisphere. If the, presumably overlapping, neural assemblies needed to handle overlapping tasks are clustered together, this would lead to hemispheric specialization.

Such constraints must apply to sentences. One can postulate that the determining focus (a temporally-organised sequence) is localised in one, presumably the dominant, hemisphere (and acts as a

frame) but that this sequence also has access through commissural fibres to neural traces (contents), perhaps at multiple sites, in the other hemisphere. Such access could provide the basis for the recombinational generativity of the process.

9. Working memory, the minimalist program and the Saussurean sign

Hemispheric specialisation and the phenomena of dominance can be related to the concept of working memory. Three components—the phonological loop, within which acoustically coded information is retained for a period of seconds (corresponding to 'primary' or short-term memory), the visuo-spatial sketch pad, from which spatial information can be retrieved and the 'executive', which determines the direction of thought or action—are recognised (Gathercole and Baddeley, 1993).

In terms of the above theory of hemispheric specialisation, it seems clear that, for the reasons outlined by Ringo et al. (1994), phonological loop activity would necessarily be confined to one hemisphere, presumably the dominant one. Conversely, the functions performed by the visuo-spatial sketchpad correspond quite closely to those of the non-dominant hemisphere. According to the 'spatialisation of form' hypothesis [see Lakoff (1987); Deane (1993); Armstrong et al. (1995)] sentence structure requires a reference frame that is extended in at least two-dimensional space, within which:

(1) components, such as subject and object, can be linked;
(2) constituency relationships are understood as part-whole correspondences; and
(3) syntax can be related to the bodily schema. The parallel-processing capacity of the non-dominant hemisphere provides such a reference frame.

The 'executive' (a suspiciously 'homunculoid' element) must clearly interact with both components; as a term, it appears to describe the process of ordering sequences, for example in the case of language within and between sentences. If the thread of continuity is in the phonological loop in the dominant hemisphere, it seems that the 'executive', which is often considered to be a frontal lobe function, must be located, along with the linear output sequence, primarily within the dominant hemisphere. As a functional entity, it has affinities with Gazzaniga's 'left brain interpreter' (Gazzaniga, 1992).

In the 'minimalist program' of universal grammar (Chomsky, 1995), a distinction is drawn between 'logical form' (LF) and 'phonetic form' (PF), the former representing the assembly of the lexical and syntactic components of the sentence, and the latter its phonetic expression with critical functions occurring at the interface. Logical form precedes, and interacts with, phonetic form, the ultimate configuration of the latter being achieved at 'spell-out' at which point the two components separate, and achieves its final output structure.

Phonetic form bears a relationship to the phonological loop component of short-term memory. In the current theory, it is located in the dominant hemisphere and is assumed to have a purely sequential (unitary and temporally organised) form. The key functional characteristic is not phonological or phonetic but its sequence, i.e. its linear form. According to de Saussure (1916):

> a primary characteristic of the spoken sequence is its linearity...In itself it is merely a line, a continuous ribbon of sound.

Logical form, however, would be expected to be spatially distributed, to be located, at least in part, in the non-dominant hemisphere, and to interact with the dominant hemispheric sequence ('phonetic form') through commissural connexions. The notion that logical form has a neural representation that is in some way different from that of phonetic form, that it is located principally in the non-dominant hemisphere and has a distribution that is partly spatial (allowing an element of parallel processing) has implications for the neural basis of these distinctive components of the language process. Paivio's (1991) dual coding theory postulated that cognitions exist in two interconnected forms—verbal ('logogens') and non-verbal ('imagens'). In terms of the current theory, these are considered as the dominant and non-dominant hemispheric representations, respectively. In

Table 2
The mechanism of cerebral hemispheric dominance

	Dominant	Non-dominant
de Saussure (1916)	Signifier	Signified
Paivio (1991)	Logogens	Imagens
Chomsky's minimalist theory (Chomsky, 1995)	Phonological form (PF)	Logical form (LF)
Working memory (Gathercole and Baddeley, 1993)	Phonological loop (and executive)	Visuo-spatial sketchpad
	1D, linear (temporal)	2-D (spatial)

Saussure's terminology, it is the non-verbal image that represents the entity that is 'signified' (see Table 2).

Each of these concepts is consistent with the view that the mechanism of language includes two components, one of which is more 'temporal' and the other more 'spatial' in character. What is added here is the hypothesis that these components are the complementary representations of the linguistic 'sign' in the two hemispheres, the differences arising from the intrinsic and genetically determined anatomical deviations in growth of the two hemispheres in man, and that the critical functional constraint arises from the physiological necessity for the linear or output sequence to be confined to one hemisphere. 'Generativity' is a secondary consequence of access to the spatially distributed information encoded in the non-dominant hemisphere.

Crucial information on the genetic mechanism is provided by the phenomena of the sex chromosome aneuploidies (see Section 7 above). Lack of an X chromosome (as in Turner's syndrome) is associated with deficits in spatial processing, and an extra X (as in XXY and XXX syndromes) is associated with deficits of temporal sequencing (Money, 1993). These syndromes thus define the boundaries of language function and identify its critical functional components—a temporal sequence in the dominant hemisphere into which is integrated the spatially distributed information from the non-dominant hemisphere.

10. Nuclear symptoms as anomalies of hemispheric specialisation

The concept of psychosis as a failure of hemispheric differentiation has precedents [for a review of concepts in the 19th century, see Harrington (1987)]; in 'A New View of Insanity: The Duality of Mind', A.L. Wigan (1844) put forward the view that 'a separate and distinct process of thinking... may be carried out in each cerebrum simultaneously' and 'that each cerebrum is capable of a distinct and separate volition, and that these are very often opposing volitions'. He considered that the interaction of the two functionally separate hemispheres was at the root of the symptoms of insanity. Crichton-Browne (1907) and Southard (1910), each influenced by evolutionary considerations, entertained the concept of serious mental illness as a disorder of the dominant or left hemisphere. Flor-Henry (1969) on the basis of his observations on the psychoses associated with epilepsy also supported this view. However, the findings from anatomical (Crow et al., 1989; Crow, 1990a, 1993, 1997; DeLisi et al., 1997) and functional studies (Gur, 1977; Green et al., 1989; Crow et al., 1996) are consistent with the hypothesis that schizophrenia is not a disorder of one or the other hemisphere, but of the interaction between them, and specifically that there is a failure to establish unequivocal dominance. Jaynes (1990) in his book 'The Origins of Consciousness in the Breakdown of the Bicameral Mind' relates, albeit within an implausible 'evolutionary' theory, how schizophrenia might represent a regression to an earlier state of consciousness (the 'bicameral mind') in which the two hemispheres were less differentiated and the interaction between them was experienced as 'voices'.

Nasrallah (1985) proposed that a normal component of interhemispheric integration is:

> inhibition of any awareness by the verbally expressive hemispheric consciousness (usually the left) that it actually receives and sends thoughts, intentions and feelings from and to another (the right) consciousness.

In schizophrenia, this function is disturbed with the result that the left hemispheric consciousness becomes aware of an influence from an 'external' force, which, in fact, is the right hemisphere (see Table 1). According to Nasrallah, Schneiderian delusions, such as thought insertion and withdrawal, and delusions of control might arise in this way, although the concept of a loss of normal inhibition provides no more specific an explanation than that there is a failure of inter-hemispheric integration.

In the context of the present hypothesis, first rank symptoms take on a new significance. They are clues to the cerebral organisation of language, the primary function of which is to communicate with another person. As argued above, this process requires a complementarity of function between the hemispheres, with one component the phonological loop, representing a linear and uninterrupted sequence, necessarily localised in the dominant hemisphere. From the fact that the flexibility (or generativity) of language must be contributed from the other hemisphere, and that, in some sense, this contribution exists in a spatial or 'distributed' form, it follows that abnormalities of inter-hemispheric connectivity will be associated with deviations in sentence production and the train of thought, although the form of these anomalies cannot be predicted without a more specific theory of the nature of the interaction. The true significance of the first rank symptoms of schizophrenia is to chart out the boundary conditions of language, to depict language 'at the end of its tether'.

Of possible relevance are the phenomena of indexicality (Lyons, 1995). A feature of human language is that it is a two-way system—sounds are decoded and generate meaning, and meanings are encoded into sound—the so-called 'bi-directionality of the Saussurean sign' (Hurford, 1992). The general principle of linguistic communication is that symbols are held in common by speakers of a given language, and by means of the bi-directional mechanism can be used as exchangeable tokens. However, as Hurford points out, there is a class of words, the deictic (or indexical) pronouns 'I' and 'you', for which this is not true. The referent is not fixed, and in the course of a two-way conversation, the meaning to be attached to these symbols must be switched back and forth, according to whoever is the speaker. It is an aspect of this process that has become deviant in association with the first rank symptoms—meanings and intentions that are internally generated are attributed to another person or outside agency (see also Lakoff, 1996). It is also relevant that some children, perhaps those who are at risk of semantic–pragmatic disorder, i.e. who are within the spectrum of autism/Asperger's syndrome, have difficulty in establishing the use of these pronouns. Dysfunction can occur early, but it can also occur late when the language mechanism is reaching its plateau of development, and when it does so, it uncovers something about the role of the two hemispheres in the bi-directionality of the Saussurean sign.

11. The nature of the brain changes

If psychotic illness is a part of the genetic variation that is common to *Homo sapiens*, this fact has implications for understanding the nature of the brain changes. It cannot be expected that there will be a pathological process that is specific to this condition but rather that the brain changes will represent an extreme of variation that is present in the population as a whole. Three gross morphological changes in schizophrenia are now relatively well established—a degree of ventricular enlargement, a small reduction in cortical mass, and loss of the asymmetries that are characteristic of the human brain (Crow, 1990b, 1997). These changes represent a shift from the mean of the general population, which, in the case of the well-studied ventricular enlargement, is known to occur without an increase in variance. The three changes must be related. A simple interpretation is that symmetry of development of the cerebral cortex implies a smaller, and perhaps less convoluted cortex, and that this in turn means that the ventricles (which decrease in size as the cortex develops) will be larger.

To which anatomical pathways do these varia-

tions in brain structure relate? What critical connexions are variable between individuals in a way that they are subject to continued evolutionary selection? The answer must be that the variability is associated with those anatomical connexions that separate *Homo sapiens* from a precursor hominid species and are associated with the speciation characteristic of language. These are the transcallosal connexions that vary with the degree of asymmetry between the hemispheres, and that continue to develop late in ontogeny. We can envisage that these connexions retain their plasticity throughout the reproductive period of adult life, that the extent to which they connect homotopic areas on the two sides of the brain is variable between individuals and that this variability is associated with an important dimension of language ability in the population as a whole. It is the precise integration of this trajectory of development with the plataeu of brain growth that is the subject of continuing selection. In a proportion of individuals, the timing is such that the inter-hemispheric interaction generates phenomena (including the first rank symptoms of schizophrenia) that are distressing to the individual and disruptive to interpersonal communication but reveal critical aspects of the neural mechanism of language.

12. Overview, implications and predictions

This essay presents the most recent version of a developing theory (Crow, 1990a,b,c, 1993, 1995a,c,d, 1996a,b) that attempts to describe and account for the phenomena of psychosis in an evolutionary context. This section summarises the components of the concept, details their implications and attempts to identify testable predictions.

The components are

(1) That the phenomena of psychosis are continuous and not categorical. There are no disease entities in the sense that there is a discrete state that bears a one-to-one relationship to a causal agent. The implication of this is that the psychoses are but the extremes (albeit highly maladaptive) of variation in the normal population.

(2) The most characteristically psychotic, i.e. least understandable, phenomena—the nuclear symptoms of schizophrenia—are the case that proves the rule. If these phenomena are, as the WHO Ten Country Study suggests, universal in human populations, they can hardly be regarded as unrelated to human psychological structure—they are an index of its intrinsic variability and a pointer to the nature of the key functions. If these symptoms are invariant across populations, then it would be predicted that other psychiatric syndromes, e.g. mania, anancastic states, if they can be sufficiently reliably defined, will also be found to be so.

(3) Given that the variation associated with psychosis is universal, and that it is biologically disadvantageous, it follows that its origin is as old as the species and that there is a necessary connection between the persistence of the variation and the nature and survival of the species. This argument leads to the unexpected conclusion that the genetic variation associated with psychosis is a reflection of the speciation event—the genetic transition to modern *Homo sapiens*. It also follows that the genetic variation is associated with the speciation characteristic of language.

(4) There appears to be only one current hypothesis that can account for this transition—that the brain became 'lateralised', or specialised in hemispheric terms, in a way that was not previously the case. The genetic change that allowed this to happen (the speciation event) generated the capacity for language along with a dimension of diversity in the human population that included the predisposition to psychosis. The prediction is that a gene for cerebral asymmetry will carry the variation that predisposes to psychotic illness.

(5) A locus for the asymmetry factor (and the speciation event) on the sex chromosomes in the class of X–Y homologous genes is predicted on the basis of (i) the psychological concomitants of sex chromosome aneuploidies; and (ii) an association between sex and handedness. Such a location can explain sex differences (for example in age of onset of psychosis, and in verbal fluency and spatial ability), and these would be maintained by the

force of sexual selection, i.e. differences in the criteria for mate choice in the two sexes. This prediction can be tested in investigations of linkage for asymmetry and psychosis on the X chromosome.

(6) As a result of this genetic change, some neural process, on which the evolution of language was dependent, became confined to one hemisphere. This component, it is suggested, is the linear output (phonological) sequence. Because it is a temporal sequence, it is one-dimensional, but each component has associations (through the cerebral commissures) in the non-dominent hemisphere that are not so constrained, but are two-dimensional and spatial. This 'bi-hemispheric' theory of language can account for the contrasting 'syntagmatic' and 'paradigmatic' aspects of language to which de Saussure drew attention, i.e. to its generativity.

(7) As evidenced by anatomical (i.e. radiological and post-mortem) and functional (e.g. handedness) studies, schizophrenic illnesses are associated with a failure of lateralisation; these illnesses, it seems, represent one extreme of the variation by which the critical components of language are allocated to the two hemispheres. Nuclear symptoms tell us something about the nature of the language mechanism, that in addition to the restriction of the linear output sequence to the dominant hemisphere, some component of the process of hemispheric specialisation relates to 'indexicalisation', the distinction between self- versus other-generated references. Thus, the consequence of the view that psychosis and language have common evolutionary origins is that it is only through the phenomena of psychosis that it will be possible to understand the mechanism of language.

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