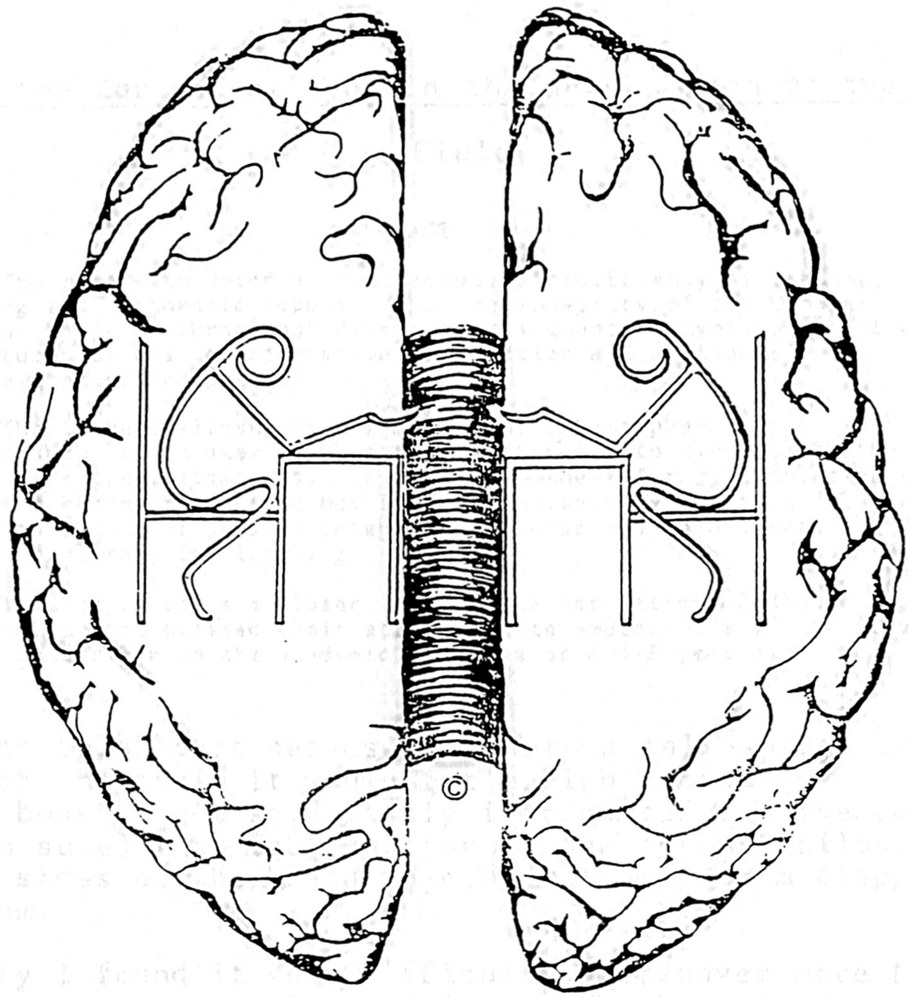

THE ROLE OF THE CORPUS CALLOSUM IN THE ACQUISITION OF THE '3 R's'

A paper presented by

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ABSTRACT

The ease with which a child acquires proficiency at reading, writing and arithmetic depends upon the integrity of the Central Nervous System. Throughout development sequential myelination of CNS structures allows for maturation of function and hemispheric specialisation to develop.

The Corpus Callosum is the major inter-hemispheric communicator and as such it mediates between the hemispheres to synchronise their particular specialisations. It is one of the later structures of the brain to become myelinated but its maturation plays a vital role in the fine tuning of sensory integration, motor and co-ordinational skills necessary for learning.

This paper takes a closer look at the maturation of the Corpus Callosum and associated brain structures to explain the influence of their maturation on the academic progress of a 5-8 year old.

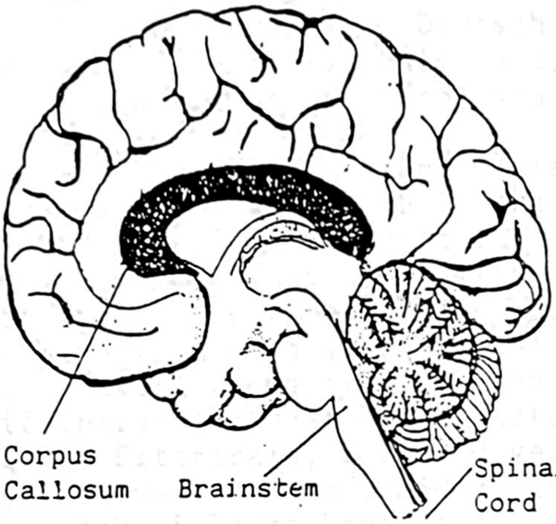
You might think that because the corpus callosum joins the two hemispheres of the brain it would get a high profile in neuroanatomy books. Not so. Lashly is reported to have commented (jokingly I'm sure) that the function of the corpus callosum is to hold the two sides of the brain together to stop them flopping onto the brain stem.

Initially I found it very difficult to discover more facts than that it is a most complex and intricate thick bundle of millions of nerve fibres which connects the two hemispheres (see Fig 1b); it is by far the largest fibre tract in the brain (Fitzgerald, 1990); it is one of three commissural fibres which interconnect and transmit impulses from regions in one cerebral hemisphere to similarly placed regions in the other cerebral hemisphere; it is concerned with short term memory, and with transferring learned tasks from one hemisphere to the other. It is then a facititator and an integrator but, being merely a bundle of nerve fibres, does not initiate functions of its own.

Only last year Dorothy van den Honert wrote that 'Neurology labs have for some years now been pumping out disconnected facts which, if properly assembled, are potentially extremely useful to SPED teachers'. By presenting this paper today I am hoping to make a start on this very complex task.

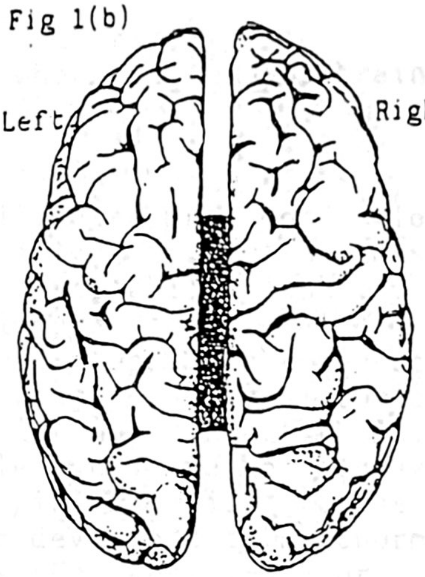
My plan is to describe something of what is going on in the corpus callosum and related structures during the years when a child is expected to learn the skills of reading, writing and arithmetic. The intention is that the paper should appeal most particularly to teachers and parents of those children who often bewilder us all. If it also entices those of an academic persuasion to fill some of the many gaps that exist here I'm sure that would be of benefit to us all.

Fig 1(a)



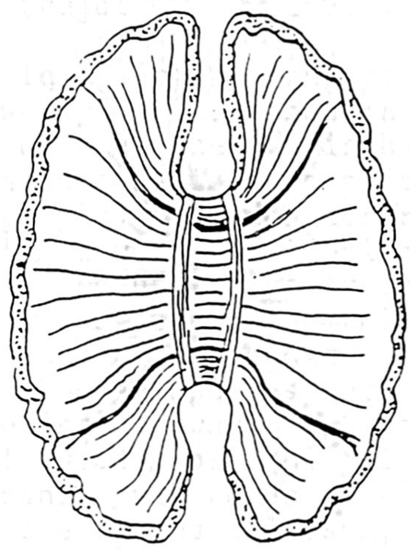
The Corpus Callosum inside the right hemisphere.

Fig 1(b)



The Corpus Callosum seen from above.

Fig. 1(c)



Corpus Callosum (horizontal section just above eyebrow level).
(Adapted from Fitzgerald, 1990).

First though an important point. The processes which the **corpus callosum** integrates, smooths, speeds up and progresses will only be as good as specialised areas of the brain and their interconnections can make them: its maturation and functions can only be realistically considered in the light of the systems which it serves. Principal of these, in the context of academic performance (during the years under consideration here) are the **cerebellum**, the vestibular and the reticular formation (see Fig. 4). These older, earlier maturing areas of the brain eventually act together to control posture, muscle tone and equilibrium: more will be said of them later.

The corpus callosum is present at birth though incompletely developed (Springer & Deutsch, 1989). It appears disproportionately small in cross section when the neonate brain is compared with that of the adult (Zeki, 1993).

It begins to myelinate (ie. develop a fatty sheath of insulation round nerve pathways which facilitates fast conduction of impulses) in its posterior part (see Fig 1c) at about 3 weeks of neonate life (Remahl & Hilderbrand, 1990) to establish links, very gradually, with the **brain stem** and **spinal cord** (see Fig. 1a). The myelination of the **corpus callosum** continues steadily throughout the first decade of life. However, this process can be disrupted if intra-uterine and post natal nutrition is insufficient (Holt, 1991; Fitzgerald, 1990); developmental milestones are not achieved (Wisniewski & Schmdt-Sidor, 1989); pathologic conditions arise (Dambska & Laure-Kamionowska, 1990); brain development is abnormal (Reiss et al, 1986); vaccine damage occurs (Coulter, 1990) or perinatal courses are complicated (McArdle et al, 1987).

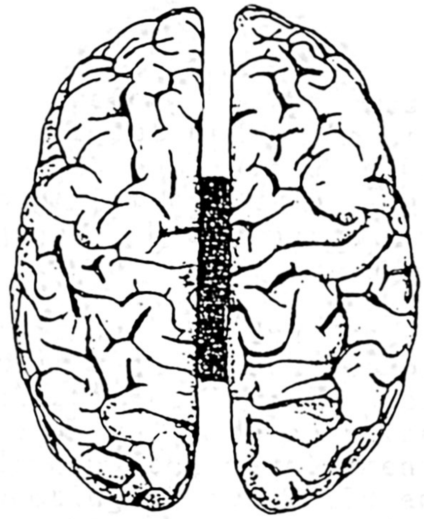
The **corpus callosum** continues to increase in size 'as long as human mentation expands, up to the middle 20's' when people attain their maximum level of speed and effectiveness in cognitive processes and skills (Pujol et al, 1993).

As you may know in a normally functioning brain each hemisphere has its own specialisations in which it overrides the supporting functions of the other hemisphere. In reading we are used to regarding the left hemisphere as the dominant one because (in the majority of people) it takes control of the major part of language function. If we were considering music then the right hemisphere is dominant because it controls, rhythm, tone, pitch and intonation: it plays a supporting role to the left hemisphere in these important aspects of language (see Fig 2). When the system is stable the two hemispheres work together to perform tasks in a specific and predictable way, each needing the help of the other in a reciprocal process of inhibition and arousal. Like an orchestra the brain can be viewed as an assembly of specialists but it is the conductor, the corpus callosum, who cues the soloists.

The **corpus callosum** mediates competitive, compensatory and collaborative functions and synchronises them so that duplication of effort is prevented. Thus the integration of analytic/verbal functions (left brain) and intuitive/spatial functions (right brain) maximises efficiency in behavioural performance (in reading, writing and arithmetic). A disorganised brain will make excessive demands on the body's supply of blood sugar and compromise its well being.

When speaking to the Orton Society in 1972 Dr Michael Gazzaniga suggested that difficulty with the rapid and accurate exchange of information between the hemispheres combined with a failure to develop task-specific hemispheric dominance, might result in the sort of learning difficulties which come under the wide umbrella of 'dyslexia'. (More information can be found in van den Honert, 1994).

Fig. 2.



Left hemisphere	Right hemisphere
Precisely organised	Diffusely organised.
Obtaining information in a sequential linear manner. Observing/analysing details.	Obtaining information in a simultaneous, holistic (Gestalt) manner. Grasping overall organisational pattern
More focal, precise, organisational with similar functional units located near each other. May facilitate precise coding needed for speaking.	Activated for discrimination of forms and directions. Synthesising information from disimilar inputs.
Achieving and producing language. Thought processes which find expression in linguistic form.	Picking up non-verbal stimuli: environmental sounds, speech intonation, complex shapes/designs, visuo-spatial percep. Drawing inferences.
Recognition/recall of verbal material and speech sounds. Sequential, analytic. Time dependent, temporal ordering: touch and movement duration. Syntactic analysis of speech/reading. Performing mathematical calculation	Alignment of numerals in calculations. Mathematical judgement and reasoning.
Sound-symbol relationships for consonants, word recognition, reading comprehension. More involved in everyday reading.	Sound-symbol relationship for vowels (these are musical). Appropriate tone and emphases/emotional tone of spoken word. Pitch, melody.
Sequencing movements. Performing movements and gestures on command. Adept at generating rapidly changing motor patterns eg. involved in fine control of hands/vocal tract.	Sustaining a movement or posture.
Expression of positive emotion.	Expression of negative emotion Perception of emotion Spontaneous smiling.

From: Fisher et al, 1991; Springer & Deutsch, 1989.

It is important that perceptual processes should be established before they are put under the stress of being used in a learning situation. As Furth and Wachs (1975) emphasised 'A child who does not have the habit of co-ordinating visual attention across a horizontal sequence should not have to acquire this co-ordination at the same time as he is trying to learn to read'.

Thus before we expect our children to read, write and work arithmetic it is essential that maturation of parts of the brain responsible for prerequisite skills should be complete and well integrated. In other words we as teachers and parents should have enough basic understanding of the development of the brain to know whether what we are expecting of our children is reasonable. A few examples might emphasise this point: Pavlidis and Miles (1987) stated that sequential order skills do not become accurate until at least the age of 7 years; de Quiros and Schragar (1979) explained that sound localisation at ear level is not precise until 6-7 years; and Ayers (1979) wrote that sensory interconnections are not complete in the brain until around 10 years of age. These points will be returned to below.

Added to this Morrison (1985) assessed that learning skills can be delayed by as much as two years by environmental factors in apparently 'normal' children! It is not surprising that some children proceed more slowly or more individually than we have perhaps been trained to expect? If you are not convinced stay with me.

As I have said, it is essential that functions of the central nervous system should mature and be adequately organised and integrated, before cognitive learning begins. There is an important sequence to this maturation with each stage of development contributing to the one which follows it. If this does not happen the process of learning will be disrupted at some stage: not necessarily immediately.

Bakker's (1990) proposals of how a child learns to read will serve as a useful illustration of how perceptual processes need to develop at specific times, and in sequence, for particular purposes. Bakker suggested that when a child begins to learn to read there is an initial need for an appreciation of spatial arrangement; an ability to discriminate shape and form, and an awareness of direction. These are functions of the right hemisphere (see Fig. 2). His work with non-reading, initial reading and advanced reading groups demonstrated that as these perceptions become more automatic there is a need for a change in reading style and thus a gradual switch from the right to the left hemisphere. This will speed up the reading process and develop the more mature sequential, syntactical, and analytical aspects of reading, and also give greater emphasis to a linear style of processing.

Bakker deduced that up to the age of approximately 8 years children whose development is proceeding normally read best in the left visual field and favour the left ear (ie. using right hemispheric processing). At approximately 8 years the switch is made to the left hemisphere, the right visual field and the right ear when hemispheric specialisation assumes a more adult pattern. Remember this switch because I will refer to it later.

Bakker reasoned that if the hemispheric switch does not take place efficiently the reader's style remains typical of right hemispheric processing, continuing to be responsive to perceptual characteristics of the text. In this case reading, although accurate, will be slow and fragmented.

On the other hand a failure to begin with the perceptual right hemispheric stage would result in reading characterised by speed, but inaccuracy, with omissions, additions (of letters) and word 'mutilations'.

Rourke (1988) described the right hemisphere as 'more intermodal and integrating in style', and needing more varied and complex inputs from a wider variety of sources than the left hemisphere. This might explain the interesting learning styles of our right brained children described by Vitale, 1982. Like the right hemisphere, the left is dependent upon connecting fibres within the brain but once learned, the skills for which it is specialised become more located and less dependent upon the right. If we consider Bakker's and Rourke's evidence in concert we can begin to appreciate how the organisation of the adult brain matures and its specialisations become established.

This prompts the thought that if we encourage a child to read in a mature style before s/he is 'ready' we might be detracting the brain from an important stage in learning to integrate sensory motor information. For example the integration of visual and sound sensations, with those from the hands and fingers, provides a basic foundation for the much later development of written work. Training in cognitive skills before a child is developmentally mature enough will promote inappropriate pathways in the plasticity of the young brain. Learning will be more of a mechanical than a perceptually integrated process, and thus will suffer in later years when higher order skills are demanded, eg. analytical thinking and comprehension.

Bakker has drawn our attention to the importance of gradual and secure maturation and interaction of functions. However, those he described must themselves be supported by structures which begin their development soon after conception. These must have achieved a high level of efficiency very early in life. A necessarily brief description of them follows but for a more comprehensive understanding I recommend de Quiros and Schragar, 1979, and Fitzgerald, 1990.

The vestibular system (the utricule, saccule and semi-circular canals of the inner ear) (see Fig.3) is the very first among all the sensory nerves to be myelinated (de Quiros and Schragar, 1979;

Bainbridge-Cohen, 1986) and is dedicated to posture, equilibrium, muscle tone and spatial orientation. Working closely with the **vestibular** is the **cerebellum** (see Fig. 4b): interconnections between these two are already myelinated at birth which is a testament to their importance as structures underpinning maturation and learning.

The **cerebellum** is the principal organ regulating co-ordination of muscular activity. As such it is part of the foundation for balancing our body posture and adjusting eye movement in response to head movement as we achieve mobility. It allows for the training of controlled and skilled co-ordination of muscles, joints and tendons throughout the body and eventually pre-programmes fast voluntary movements of all kinds. At about the age of 4 years its influence begins to project strongly to the arm and hand areas as a preparation for the extremely complex movements they will soon be required to perform.

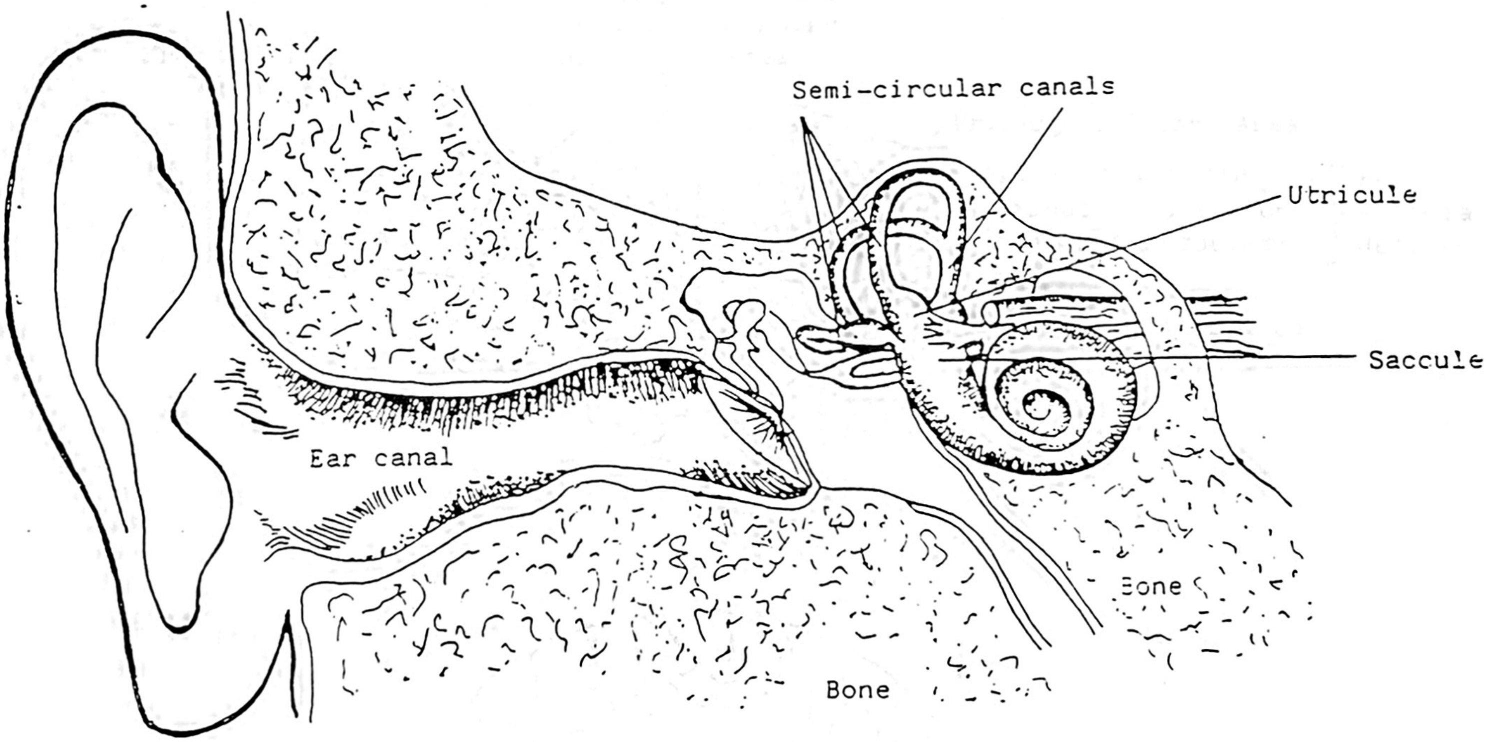


Fig. 3. Diagram to show the position of the Vestibular in the inner ear.

<u>If</u> the functions of these delicately balanced mechanisms are successfully perfected over our early years we have the postural stability to train eyes and ears to work in a co-ordinated way to support essential learning about ourselves, our space and our environment.

The co-operation of the reticular formation (see Fig. 4b) is important in this partnership for it permeates the core of the brain and extends its influence to all the body's automatic functions. It acts as a regulator, an organiser and an arouser of and for all messages passing between the brain and body. In this way the co-operation of the vestibular and the cerebellum can be managed to achieve selectivity of perception and attention and maintain alertness. This does not take full effect until about 6 years of age. The reticular formation also regulates our sleep-wake cycle, so its influence on the brain is fundamental to the processes of life and learning.

What I have just described in four very inadequate paragraphs takes years to evolve but must be working smoothly (although not yet fully efficiently) by the time a child enters school, so that necessary link-ups can take place progressively to support the increasingly complex skills needed for reading, writing and arithmetic.

Fig. 4(a).

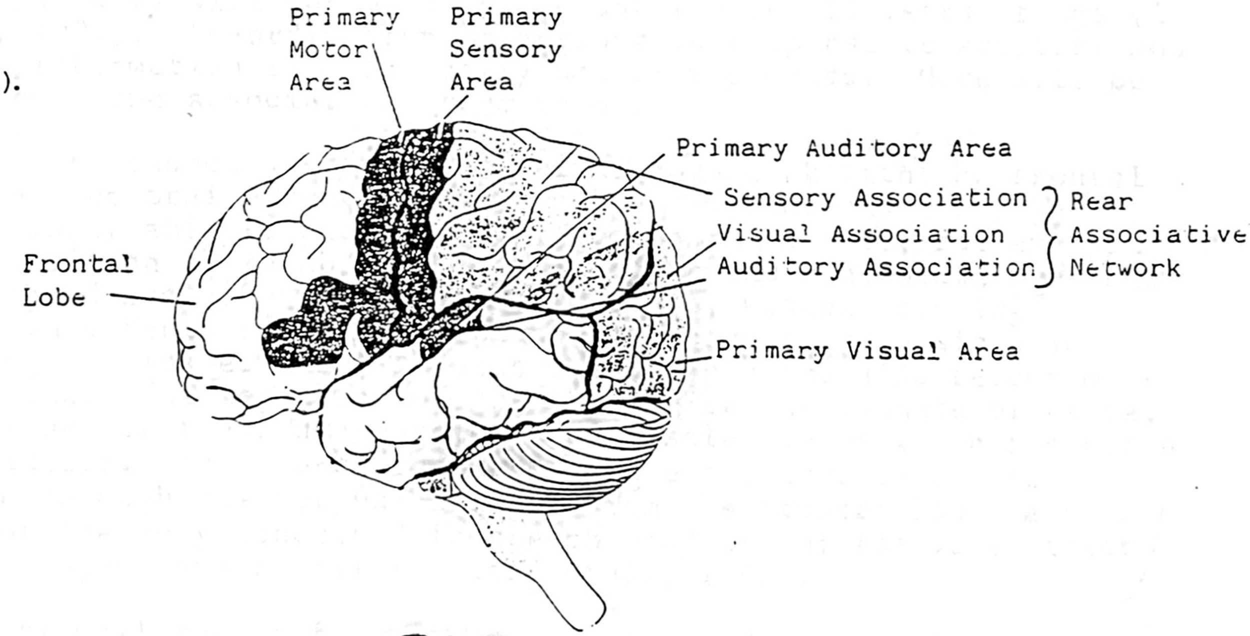
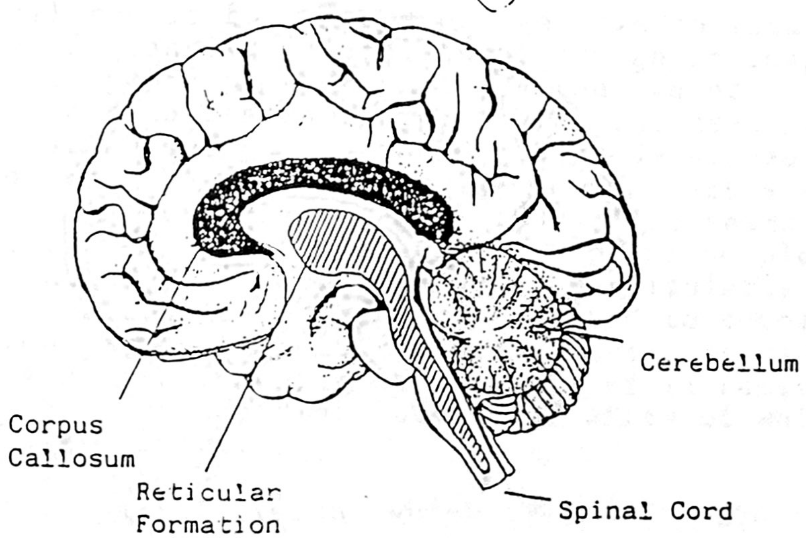


Fig 4(b).



Before considering the maturation of those skills a brief sketch of the child just before s/he enters school (5 years of age in Britain) will set the scene.

At 4 years old the **corpus callosum** is myelinating past the primary sensory and motor areas (ie. the sensori-motor area: see Fig 4a) (Yakovlev & le Cours, 1967; Galin et al, 1979), so external sensory inputs from eyes, ears, hands, and skin and internal messages from muscles, joints and organs are beginning to integrate more efficiently. The child will have better awareness of the body and its movements in space (kinesthesis), and of muscular movement for reciprocal co-ordination. These sensations will be related to auditory and tactile feedback. This is of particular importance in the development of writing and will continue to mature until 10 years of age when the growth of sensory interconnections is virtually complete in the brain (Ayres, 1979).

The **rear associative network** of the brain begins to link up visual to auditory to motor regions (see Fig. 4a). Myelination of these pathways will not be complete until about 15 years of age (le Cours, 1975). Co-ordination of actions in response to auditory and visual information is a gradually maturing process. More will be said about the **association areas** below.

Motor connections from the **spinal cord** link with the **frontal lobes** of the brain (see Fig. 4a) so the 4-5 year old is increasingly able to plan and copy complex movements, for example the opposition of thumb and finger to grip and manipulate a pencil. Motor speed and accuracy begins to improve, visual scanning, selective attention and motor planning become more feasible so learning becomes easier. Motor speech mechanisms also become more controlled. The mechanics of speech require co-ordinate bilateral (both sides of the body) movements of muscle groups which control articulation. This co-ordination is made smoother by fibres passing through the **corpus callosum** from the frontal lobes and to parts of the body concerned in speech production: the vocal tract, mouth, tongue, and facial muscles (Brain, 1987).

Most children of four years of age have no idea of the conservation of quantity regardless of change in shape: they are very dependent upon what they see. By the age of 6 years, when links have been established in the brain, children give answers which show that an unresolved conflict has developed between what they see and what they think. During these years a permanent number concept is evolving (Piaget, 1941). It seems likely that pre-school children have 'a coherent set of principles for reasoning about number' (Gelman, 1972), particularly if the numbers involved are small, but if they are expected to succeed in arithmetic the permanent number concept must have developed securely. 'A number is only intelligible if it remains identical with itself whatever the distribution of units of which it is composed (Piaget, 1941).

Binocular spatial vision, which came in at about 12 months of age, has been reinforced by improving visual acuity over the years (de Quiros & Schragar, 1979) to allow for the development of skilled spatial organisation and the ability to correlate symbols with language, but fine eye control is not yet mature enough for sustained reading. Visual discrimination of letter forms improves gradually between the ages of 4-8 years beginning with closed shapes and proceeding to the joining of lines and curves.

From 5 years on **vestibular proprioceptive** actions which work to inform higher levels of the brain about body posture, are also influenced by the **cerebellum** thus co-ordinated movements become regulated and controlled for finer, more skilled application, for example writing. With this improving body equilibrium lateral integration begins, ie. the two sides of the brain start to interact, so functional hemispheric specialisation begins to develop. Children start to sort out their laterality (ie. preferred eye, ear, hand and foot), but this may not be complete until about 8 years of age. Orton (1925) suggested that 'those children .... in whom clear dominance has not been well established before they begin to learn to read, probably have more trouble with the reversal of letters'. Again an emphasis on the maturation of processes before learning to read and write becomes a priority.

The manual region of the left **motor area** (located in the **frontal lobe**) connects through the anterior part of the corpus **callosum** (see Fig. 1c) to the manual region of the right **motor area**. With this mediation between the hemispheres bilateral integration and reciprocal bilateral movement develop more securely at 5 years. This co-ordinated co-operation of the two body sides can only become finely tuned if successful 'division' of the body was achieved between 3-4 years to allow, for example, each hand to perform skilled actions independently of the other.

Training of a task in one of the **motor** areas is transferred automatically to its counterpart so that the ability is there to write with your left hand if you are right handed and vice-versa. Albeit some practice is needed for perfection. Gaddes (1985) suggested that training which modifies a localised area of one hemisphere is carried, via the corpus callosum, contralaterally to the other hemisphere. **The corpus callosum** thus allows transmission of memory and learning.

There is an improvement in interhemispheric transfer of tactile information at this time. Recognition of two and three dimensional objects by touch alone (stereognosis) is mediated by the **corpus callosum**, allowing the performance of complex co-ordinated actions like fastening buttons without looking: the one hand 'knows' what the other is doing so that they can co-operate. Van den Honert writes that tactile information is poor until about 6 years of age. The motor areas function closely with their adjacent sensory areas as the sensori-motor area. This integration of function is essential as movement is guided and enhanced by sensation.

Vestibular functioning should be well developed by 6 years of age thus the complex links between the **vestibular** and the spine become fully efficient to result in more precise postural adjustment. We can expect to see improved ocular motor responses, balance control, muscle tone and more secure body position in space. Parts of the **cerebellum** responsible for midline function respond to **vestibular** stimulation so links are in place for more efficient and complex functioning at and across the midline. This is important for smooth linear style in reading and writing particularly.

Between 6-7 years the role of the **cerebellum** is sufficiently integrated through **cerebellar-vestibular** linking to allow for fine co-ordinated movements like saccades (precise micro-movements of the eyes) to mature sufficiently to follow a line of print without head movement. Visual information that mediates ocular tracking is also transmitted to the opposite cerebral hemisphere via the **corpus callosum**. Pavlidis and Miles suggest that maturation of parts of the brain responsible for sequential control eg. saccadic movements might consititute a pre-requisite for the execution of any sequential task such as spelling and multiplication tables.

Gilbert (1953) tested 486 children from 6-14 years and found that their ability to fixate digits improved with age, the most striking improvement occurring between 6-7 years of age. Similar results were obtained by Lesevre (1964) who tested children between 5-12 years. Gilbert and Lesevre, amongst others (see Pavlidis & Miles) maintain that sequential order skills do not become established until at least the age of 7 years.

There is a multiregion brain growth spurt between 6-8 years of age, and pacemaker fibres from the **reticular formation** (see above) reach the rear **associative network** (see Fig. 4a) of the brain during this time. The influence of the **reticular formation** regulates, organises and arouses visual, auditory and sensory processes to improve attention, alertness and selectivity of perception. The child is more able to integrate and interpret sensations, for example the exact shape and texture of an object without looking, the orientation of one object to another and the sense of relationship of one body part to another. Storage of memories of past experiences is possible so present visual and auditory inputs can be related to past experiences. Through recognition and evaluation of what is seen and heard schema can be built up.

Between 6-10 years there is a large increase in the size of the **corpus callosum**. Schaefer et al (1990) detected little dramatic change before this period. This may reflect the major myelination which takes place between 6½-7½ years between the **vestibular** the **corpus callosum** and the **cerebellum**. This is vital to allow for the balancing and stabilising influence of the **vestibular**, and the regulatory influence of the **cerebellum** to be relayed rapidly between the hemispheres to all processes.

Each of the primary areas (visual, auditory and sensory, see Fig. 4a) receive the first impressions from receptors (eyes, ears, etc.) and are directly interconnected across the corpus callosum about this time. With the influence of the vestibular and the cerebellum the way is open to a wealth of new experiences and possibilities for learning. For example arithmetical calculation can become more efficient. With rapid relays across the corpus callosum: using number recognition, sequencing and computational abilities from the left hemisphere, and alignment of numerals, spatial arrangement, judgement and reasoning from the right (see Fig. 2), information can be speedily cross-checked and integrated between specialist areas. Coincidentally Epstein (1974a) noted a greater ease in learning arithmetic and acquiring reading skills at 7 years old.

With direct interconnection across the corpus callosum separate visual images are smoothly fused together at the vertical midline to form integrated wholes. The child can achieve stereopsis at midline, smooth ocular tracking, smooth convergence, stable ocular dominance and matched focusing. There is a marked improvement in perception of spatial arrangement together with a judgement of depth, distance, motion, velocity and direction. With enhancement of these perceptions comes an understanding of mechanical cause and effect (Gaddes, 1985). Letter, number and word reversals, normal until this linking across the corpus callosum has taken place, should disappear by about 8 years of age, ie. when, as Bakker suggested, the hemispheric switch takes place and the left hemisphere becomes 'dominant' to support a mature style of reading.

Where the left and right primary auditory areas come together at body midline, both in front of and behind the body, the corpus callosal connections convert monaural neurones into binaural neurones. This allows the child to place sound efficiently in relation to him/herself from either side of the vertical midline, and achieve a finer judgement of auditory distance, directionality and orientation, as well refining visual responses.

Direct corpus callosal interconnections between the primary sensory areas, which receive inputs from cutaneous, muscular and visceral receptors, are restricted to the trunk and head regions. As sensations from the vertical anterior and posterior midline of the body are fused a sense of body organisation can develop. This will allow for the composition of a body 'map' about which body information can become integrated.

From organisation about this midline children can elaborate on their personal spatial organisation and differentiate objects in external space to left, right, infront of, or behind them. Subsequently they begin appreciate symmetrical relationship in other people and then in objects, and with this the ability to recognise and copy form and shape. They develop the concept of rotating objects about their own axes. Stable spatial concepts evolve such as horizontal, vertical, centre, left and right.

Points can be related and fixed in asymmetrical space: a prerequisite for correct computation of hundreds, tens and units. By the time they are 7+ children can identify right and left on someone facing them, and by 11 years they can appreciate the right and left of objects.

Each of the **visual, auditory and sensory association areas** (see Fig. 4a) receive inputs from the **primary areas** discussed above. These **association areas** are freely connected through the **corpus callosum**, though less directly so, and their myelination comes later than that of the **primary** pathways. This is possibly because their role is more complex and allows for highly elaborate processing when more basic functions have become automatic.

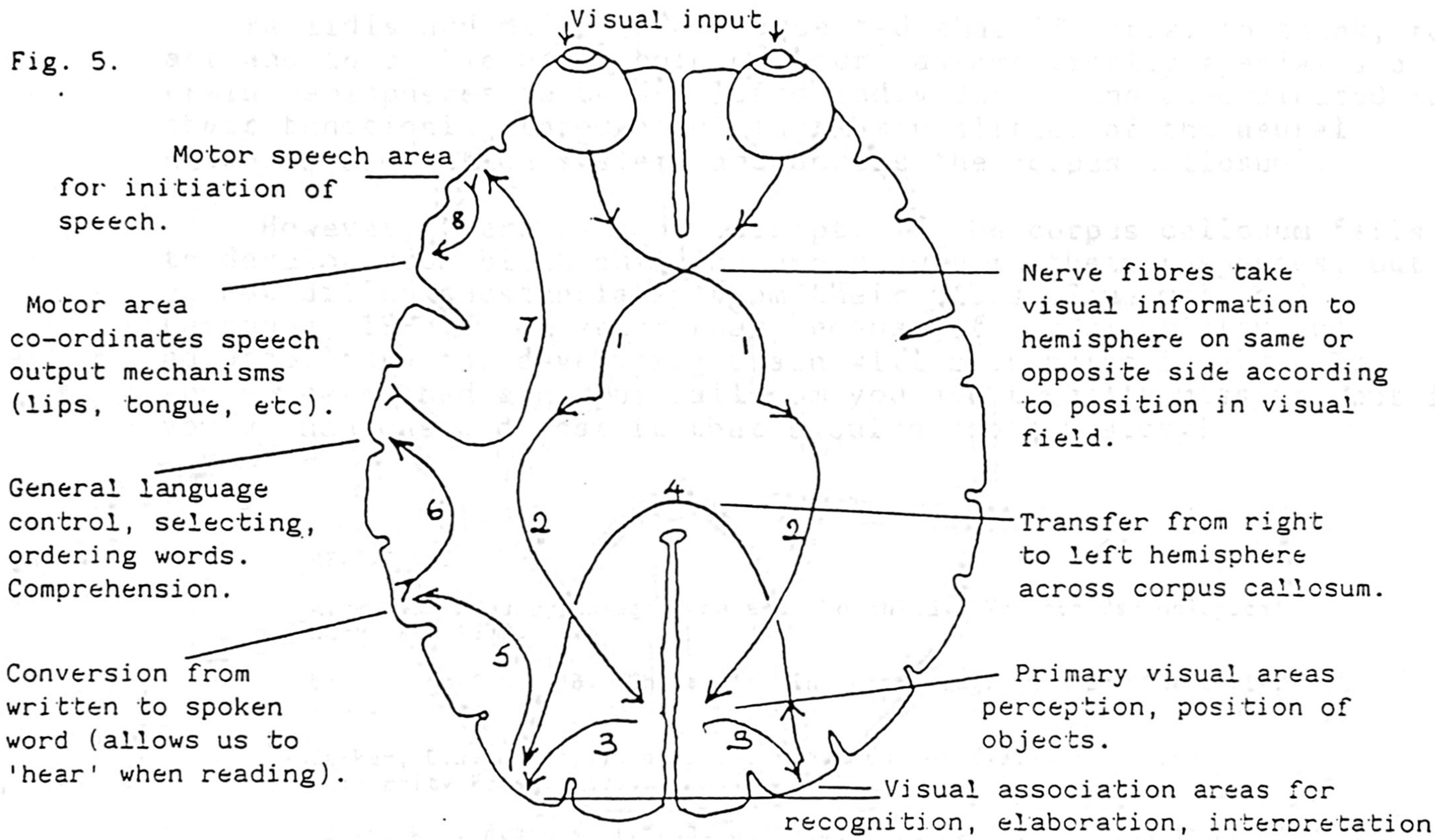
The **association area**, as its name implies, associates incoming messages with previous similar impressions of a visual, auditory or sensory nature. It provides for recognition as well as elaboration and interpretation of sensations.

As you will doubtless know each side of the body is mapped onto a specific region of the cortex of its opposite brain hemisphere, but by means of the **corpus callosum** the hemispheres exchange information so that each specialist area is aware of the messages the other is receiving. Zeki (1993) suggests that, because each area has these specific and separate connections with its counterpart in the opposite hemisphere, each contributes data to processing with a certain level of autonomy: duplication or competition of effort is prevented as the 'chit-chat' across the **corpus callosum** synchronises functions.

Such synchronisation is vital if the processes of reading and writing are to proceed smoothly, for the child must be able to recognise, integrate and interpret a complexity of sensations at speed, and sequence these effectively. 'To read [s/he] must acquire an auditory-graphic match between what [s/he] knows auditorilly and the written or printed representation of speech' (Gaddes, 1985). These are complex skills which require much 'cross talk' between the hemispheres. Gaddes asserted that written language is the last of the language skills to be acquired and is only learned naturally if all preceding stages have been successfully established.

The process of reading aloud is particularly complex. It is a receptive process beginning with the impression of letters and words which are passed from the retina of each eye to the **primary visual areas** of each opposite hemisphere, then to the **association areas** on each side for recognition. Inputs to the right hemisphere then pass across the **corpus callosum** for transformation from the written to the spoken word. Comprehension is facilitated in the left hemisphere, then inputs are passed to the motor areas where speech mechanisms are activated. An adapted diagram from Fitzgerald (1990) with my own annotations (Fig. 5), illustrates the <u>minimal</u> pathway for reading aloud and will hopefully begin to explain the co-ordination involved.

Fig. 5.



Very simplified diagram showing the main pathways for reading aloud.

Writing (and arithmetic) is something of a reversal of the reading process for verbal ideas must be converted to auditory sensations (inside the head), split into phonetic (sound) sequence, associated with letter (or number) shapes and organised in a linear (and/or an asymmetrical) style, using spatial and directional organisation and eye-hand co-ordination - and that is a much simplified description!

All this activity must take place in seconds and without conscious involvement, thus the higher order processing is left free to comprehend, analyse, be innovative and commit information to memory in an ordered and sequential way. 'Slow or degraded transfer across the corpus callosum spoils the split-second timing required for rapid cognitive activity (van den Honert, 1994).

At the age of 8 years the corpus callosum begins to myelinate its connections with the frontal lobes of each hemisphere (Yakovlev and le Cours, 1967) (see Fig. 4a). This process takes two years to complete and brings with it improvements in motor speed and accuracy, hand grip strength, motor speech, visual scanning, selective attention and planning. The brain growth spurt identified between 6-8 years slows down, concrete reasoning improves and the auditory system for language begins a new two year vocabulary building stage. (Penfield and Roberts, 1959).

Pavlidis and Miles (1987) asserted that 'To grow, to think, to act and to be [we need] both of [our] asymmetrically specialised brain hemispheres to be developed individually and co-ordinated in their functioning through the instrumentalities of the neural networks and action systems and across the corpus callosum'.

However, there is a postscript: if the corpus callosum fails to develop from birth children are slower in their responses, but do not differ substantially from their peers (Sauerwein and Lassonde, 1993). It seems that because of its plasticity and adaptability, the developing brain will reorganise itself. If you've never had a corpus callosum you don't really miss it, but if you've had one and lost it that's quite another story!

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