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Understanding language from brain disorders

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Abstract

The word neuroscience is modern, and yet the study of the brain is as old as science itself. Historically, scientists interested in the nervous system came from different specialties: medicine, biology, psychology, physics, chemistry, mathematics. The revolution of Neuroscience came from the fact that these scientists realized that the greatest hope for understanding the functioning of the brain lies in a firmly interdisciplinary approach, a combination of traditional methods and modern technologies, to reach an updated vision of brain function and open new horizons. Language is universal in human societies. Highly specialized brain areas are used. Experts consider that there are about 5000 different varieties of languages and dialects in the world. The organization of these languages is very diverse, for example regarding the place of nouns or verbs. However, despite such differences in syntax, all languages convey human experience and emotions, in their finest subtleties. Many scientists consider the universality of language to be the result of the evolution of the human brain of certain organs, well devoted to this function.

Keywords

language; neuroscience; cerebral cortex ; aphasia.

فهم اللغة من اضطرابات الدماغ

ملخص

العلوم العصبية كلمة حديثة، لكن دراسة الدماغ قديمة قدم العلم نفسه. تاريخيًا، جاء العلماء المهتمون بالجهاز العصبي من تخصصات مختلفة: الطب، وعلم الأحياء، وعلم النفس، والفيزياء، والكيمياء، والرياضيات. جاءت ثورة علم الأعصاب عندما أدرك هؤلاء العلماء أن الأمل الأكبر لفهم وظيفة الدماغ يكمن في نهج متعدد التخصصات بالتأكيد، وهو مزيج من الأساليب التقليدية والتقنيات الحديثة، للوصول إلى رؤية محدثة لوظيفة الدماغ وفتح آفاق جديدة. اللغة عالمية في المجتمعات البشرية. يتم استخدام مناطق دماغية عالية التخصص. يقدر الخبراء أن هناك حوالي 5000 نوع مختلف من اللغات واللهجات في العالم. إن تنظيم هذه اللغات متنوع للغاية، على سبيل المثال فيما يتعلق بوضع الأسماء أو الأفعال. ومع ذلك ، على الرغم من هذه الاختلافات في بناء الجملة ، فإن جميع اللغات تنقل التجربة والعواطف البشرية ، بأدق التفاصيل. يعتبر العديد من العلماء أن عالمية اللغة هي نتيجة لتطور أعضاء معينة في دماغ الإنسان، مكرسة جيدًا لهذه الوظيفة.

الكلمات المفتاحية

اللغة؛ علوم الأعصاب ؛ القشرة المخية ؛ الحبسة الكلامية.

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I- INTRODECTION

Language is a formidable system of communication, which objectively has a considerable impact on our lives. You can walk into a café and order a cappuccino with a double ration of whipped cream, and you can be sure that you won't be brought a bucket of water! You can also talk on the phone to a friend thousands of miles away, and explain both the complex foundations of quantum physics, or the emotional impact your last physics class had on you. The question of whether animals also have a language is an endless debate, but what is certain is that the one we use is indeed the characteristic of man. Without language we would not be able to learn most of the things we are taught in school, and this would greatly limit our ability to act and intervene.

More than just sounds, language is a system by which sounds, symbols, and associated gestures are used to communicate. Language thus penetrates us through the auditory and visual systems, and the motor system produces both speech and writing. In fact, the processing of all this information by the brain between sensory system and motor system, is the very essence of language.

Because the use of animals to understand human language has obvious limitations, for the most part until recently the study of language has been the prerogative of linguists and psychologists, rather than neurobiologists. Thus, just about everything we know in this area derives from case studies of patients with deficits following brain injury. In this context, multiple aspects of language can be affected differentially: language production, comprehension, or the ability to name, suggesting that language proceeds from complex, anatomically and functionally different, and complementary mechanisms. More recently, functional brain imaging methods, such as functional magnetic resonance imaging (fMRI), or positron emission tomography (PET), have allowed us to begin analyzing the mechanisms of the complex circuits that.

Language is universal in human societies. It uses highly specialized brain areas. Experts consider that there are about 5,000 different kinds of languages and dialects in the world. The very organization of these languages is very varied, for example with regard to the place of nouns or verbs.

II- What is language?

Language is a system of representation and communication of information, which uses a combination of words according to well-established grammatical rules. Language can be expressed in different ways, including gestures, writing, and of course the use of spoken words. Speech thus constitutes the audible form of communication between individuals, based on the production of sounds. The ability to speak comes naturally in humans: even without formal learning, children raised in a normal language environment invariably learn to understand spoken language and speak it themselves. Reading and writing, on the other hand, require years of formal learning, and more than 10% of the world's population is illiterate.

II- 1 From human sounds to speech production

In the animal kingdom, a variety of specialized devices are used to produce sounds. However, in what follows we will focus on those at the origin of the production of language in humans (Fig.1). Producing speech requires the finest coordination of the activity of more than a hundred muscles, ranging from those that control the ventilation of the lungs, to those of the larynx and mouth. At this point, it is important to realize that all these muscles are controlled from the motor cortex. Human sounds begin when a person exhales the air contained in their lungs. Air passes through the larynx. What we call the "Adam's apple" (the laryngeal prominence) located at the neck, corresponds to the anterior part of the cartilage of the larynx. The larynx has the vocal folds, more commonly called vocal cords, representing two bands of muscles forming a kind of V. The space between the vocal cords, which is part of the larynx, is the glottis. Sounds result from vibrations of the vocal folds; A bit like the sounds emitted when you blow into a stalk of grass. If the vocal cord muscles are relaxed, however, no sound occurs, such as blowing into a rod that is too soft. This is actually what happens when we exhale air without producing speech. The production of a sound comes from the frequency of vibration of the vocal cords. Thus, a high tension of the vocal cords produces high-frequency vibrations and high-pitched sounds. Sounds have the characteristic of being susceptible to changes at several levels of the vocal system, including the pharynx (and particularly in the part of the throat between the larynx and the mouth), the mouth itself, and the nose. Finally, rapid changes in the position of the tongue in the mouth, the positioning of the lips and the palate, help to modulate the sounds related to speech production. The most basic sounds that are used in a given language are called phonemes. Different spoken languages have different and unique phonemes, which help to construct words specific to that particular language. (Patricia Kuhl, 2004)**8**

II- 2 Language acquisition

Language processing in the adult brain is conditioned by close, perfectly orchestrated interactions between different cortical and subcortical areas. But how does the brain learn to use language? Language learning, or rather language acquisition, is a fascinating process, which is characterized by the fact that it is similar in different cultures. Newborn vocalizations become babbling around 6 months. At 18 months, babies are about 150 words long and can use about 50.

At the age of 1-2 years, children use the tones, rhythms and accents of the languages to which they are exposed. Then, it is only at the age of about 3 that they are able to make sentences and use about 1,000 words. When becoming an adult, a person uses several thousand words. Moreover, after puberty the acquisition of a second language becomes more difficult. Thus, because of the difficulties of older children in acquiring a second language compared to the first language and the difficulties that may occur in the acquisition of this first language, if the child is not properly exposed to a spoken language before puberty, it is suggested that there is a form of "critical period" during development with regard to language acquisition.
The speed with which children learn their language belies the complexity of the challenge it represents. When we first hear a foreign language, it seems extremely fast, and we have trouble pinpointing when one word ends and another begins. This is one of the difficulties faced by children learning their own language. By the age of 1, however, children can already recognize the sounds of their language and words, even if they are not able to understand their meaning. (Patricia Kuhl, 2010)7
We still don't know what neural mechanisms children learn to distinguish and articulate words. Ghislaine Dehaene-Lambertz and her collaborators, working at Neurospin in Saclay, showed, using fMRI recordings, that from the age of 3 months, children presented brain activation responses to the words heard, very similar to those recorded in adults (Figure.1). Hearing speech thus largely activates areas of the temporal lobe, rather in the left hemisphere. These results do not show that the child processes language information in the same way as the adult, but they illustrate the fact that there is an early and relatively similar organization of auditory areas and language lateralization.

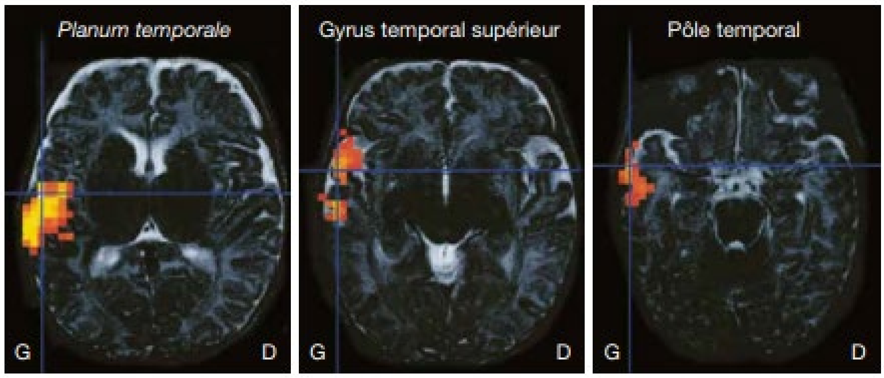

Figure.1 Cerebral ctivity evoked by listening to speech, recorded from the brain of a 3-month-old child.
Representation of the horizontal sections of the regions whose activity is significantly increased by listening to the word. These areas represent the temporal planum, the superior temporal gyrus, and the pole of the temporal gyrus. In fMRI images, the colors red, orange, and yellow indicate increased brain activity. G: left; D: right. (Ghislaine Dehaene-Lambertz, & al, 2002)3

III- Genes involved in language

Some language disorders have a familial component and are likely to be present in identical twins rather than fraternal twins. These observations suggest the intervention of genetic factors in these language disorders.
However, for many years the difficulties of characterizing the familial transmission of these pathologies have made the characterization of specific genes particularly complex.
FOXP2 and verbal dyspraxia. The way we think about how genes control language changed dramatically in 1990, with the first publication about a British family known as KE. About half of the three generations of this family studied had verbal dyspraxia, that is, an inability to produce the coordinated movements to produce language. Their speech was thus largely unintelligible, including to family members, and these individuals had therefore developed sign language to supplement spoken language. In addition to this dyspraxia, members of the KE family had great difficulty with grammatical aspects of language and, in general, had lower IQs than other family members not affected by the disease. Given that some family members affected by language disorders had normal IQs, cognitive impairment was considered language-specific and not the result of more general impairment of cognitive abilities. Brain imaging data revealed that family members affected by the disease had numerous abnormalities of motor structures, including the motor cortex, cerebellum, and striatum (caudate nucleus and putamen), compared to other family members.

III- 1 Genetic factors related to specific language deficits and dyslexia

Following the characterization of FOXP2 in the KE family and its involvement in verbal dyspraxia, various mutations of FOXP2 have been found in other individuals, independently of this family. In all cases it appeared that the simple mutation of this FOXP2 gene was at the origin of various developmental disorders affecting language. The deficits also concerned the grammatical and cognitive aspects of language, but it is not yet clear whether and to what extent these language disorders were distinct from verbal dyspraxia.

Stimulated by the findings related to FOXP2, the research showed the involvement of other genes potentially involved in other types of language disorders. For example, specific language impairment (SLI) is present in about 7% of 6-year-olds in the United States. This deficiency consists of a delay in language proficiency, which may persist in adults and is not associated with hearing problems, or with more general developmental delays. These children have difficulties learning and using words, especially verbs. Since more than 50% of these children are descendants of parents themselves affected by this problem, the genetic nature of this deficiency is hardly in doubt and a strong genetic component has been suspected.
Genetic studies of these children have identified a handful of genes possibly involved in this language disorder. Thus the CNTNAP2 and KIAA0319 genes, in addition to the FOXP2 gene. Without focusing on complex acronyms, it should just be noted that CNTNAP2 encodes the protein neurexin, a protein of the presynaptic element involved in the association of pre- and post-synaptic elements of the synapse. Neurexin plays a very important role during development, especially in allowing the correct positioning of potassium channels on the membrane of neurons. KIAA0319, on the other hand, critically participates in the migration of neurons during the development of the cortex and contributes in adults to the normal functioning of neurons.
Another language disorder better known and more common than the previous ones is represented by dyslexia. Dyslexia results in difficulties learning to read despite a completely normal intelligence. Dyslexia affects 5 to 10% of individuals, considered more common in boys than girls. This deficiency has a strong genetic component, so much so that children of dyslexic parents have about a 30% chance of being dyslexic themselves, and 30-50% of children of a dyslexic person are dyslexic. KIAA0319 is one of the genes often associated with dyslexia. Therefore, it appears that dyslexia is very present among children suffering from specific language disorders according to the definition given above, the comorbidity can reach 40 to 50% of individuals. In this case, these specific language disorders and dyslexia could have common causes or represent differential expressions of the same deficit. Like specific language disorders, dyslexia appears related to alterations in cortical development. (Vargha-Khadem Franen varga, 2005)**10**

IV- Discovery of language areas in the brain

As in other areas of neuroscience, it was not until the end of the last century that the relationship between language and the brain began to be better understood. The study of aphasia represents the best source of information to know the role of certain areas of the brain. Aphasia refers to the partial or complete loss of language use due to brain damage, most often without impairment of cognitive faculties, nor of the ability to mobilize the muscles used in the articulation of words.
In the time of the Greeks and Romans, speech was considered controlled by language, and therefore it was there that the origin of language disturbances should be sought, rather than in the brain. If the loss of language was due to trauma to the head, gargling and tongue massages were recommended. In the sixteenth century, it was established that an individual could have speech disorders without paralysis of the tongue. Yet, despite these advances, treatment still consisted of cutting the tongue, bleeding and applying leeches.
Around 1770, Johann Gesner published a relatively modern theory of aphasia, in which he described it as the inability to associate abstract images or ideas with their spoken symbols. He thought these disorders stemmed from brain damage caused by an illness. Gesner's definition highlights an important fact: in aphasia, cognitive functions may remain intact, but a specific function of verbal expression is affected.
In 1825, the French doctor Jean-baptist Bouillaud issued the idea of a loca lisation of word in frontaux lobes, but it was necessary to wait forty years furthermore so that this idea is accepted by all. In 1861, Simon Alexandre Ernest Aubertin, Bouillaud's son-in-law, reported the case of a man who had his frontal bone blown up in a failed suicide attempt. While treating this man, Aubertin discovered that if he pressed a spatula on the exposed frontal lobe while the man was talking, his speech immediately became bumped and only returned to normal if the pressure was released. He concluded that the pressure on the brain interfered with the normal functioning of a cortical area of the frontal lobe.

IV- 1 Broca's area and Wernicke's area

In 1861, a patient almost unable to speak presented himself to the French neurologist Paul Broca. This patient was called "Tan" because the only sound he could emit was "tan". Tan died shortly after he met Broca, and his brain was taken. Tan died shortly after he met Broca, and his brain was taken. Broca asked Aubertin to participate in the examination of the brain, and both concluded that, in this patient too, there was a lesion of the frontal lobes. The scientific community had probably evolved by this time, and Broca's case seems to have led to the idea that there is a language center in the brain. In 1863, Broca published a paper describing eight cases of language disorders resulting from lesions of the frontal lobe in the left hemisphere. In light of other similar cases and reports that speech was not disturbed by right-hemisphere lesions, Broca, in 1864, suggested that language expression is controlled by only one hemisphere, almost always the left. This idea is consistent with the results gained with a more modern method for determining the role of both hemispheres in language, called the Wada procedure, in which one of the hemispheres is anesthetized. In most cases, oral expression is impaired by anesthesia of the left hemisphere, not the right hemisphere. In the 1990s, functional brain imaging replaced the Wada procedure for determining hemispheric dominance in relation to language, and the results confirmed early observations. One hemisphere is said to be dominant when it appears to be more involved than the other in a given task. The critical area of articulated language identified by Broca in the frontal lobe of the left dominant hemisphere is now called Broca's area (Fig.2). In fact, Broca's contribution is very important because, in the case of language, it was the first demonstration of the existence of an anatomical localization of brain functions.

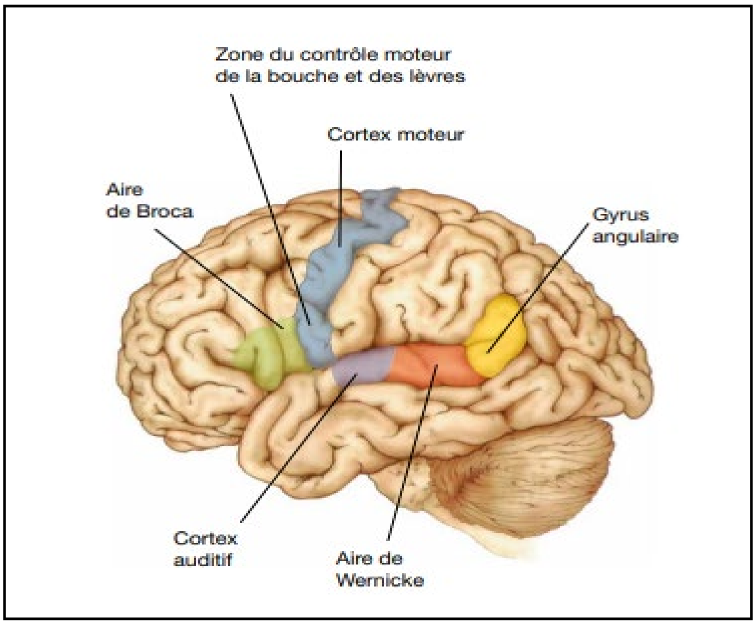

Figure .2 – Main structures involved in language mechanisms in the left hemisphere.

Broca's area is located in close proximity to areas of the motor cortex that control mouth and lip movements. The Wernicke's area of the upper temporal lobe is located between the auditory area and the angular gyrus.
In 1874, the German neurologist Karl Wernicke reported that normal oral expression is also abolished by other lesions of the left hemisphere, sitting in a different region of Broca's area. This region, located on the upper surface of the temporal lobe between the auditory cortex and the angular gyrus, is known as Wernicke's area (Fig.2), and the nature of aphasia observed by Wernicke is different from that associated with Broca's area lesions. After demonstrating the presence of two areas of language in the left hemisphere, Wernicke, along with others, sought to map language processes in the brain. Wernicke postulated the existence of interconnections between the auditory cortex, Wernicke's area, Broca's area, and speech-associated muscles, and attributed the different types of language disturbances to lesions in different parts of this complex system. Although the terms Broca's area and Wernicke's area are commonly used, it should be noted that they have some ambiguities. In particular, the boundaries of these areas are not clearly defined, and they may vary from one subject to another. Moreover, these areas may be involved in functions other than language. However, these discoveries are recent, and they only take on their full meaning after specifying what the aphasias caused by lesions of Broca's and Wernicke's areas are.

V- Understanding language from aphasia

As in the studies of Broca and Wernicke, the oldest method implemented to establish the relations between language and the brain is based on the correlations established between the functional deficits and the lesions of certain areas of the brain (anatomoclinical method). The existence of several types of aphasia, illustrated in Table 1, suggests that language processes undergo several stages and take place in different regions of the brain at once. By examining language deficits resulting from damage to different brain areas, Nina Dronkers, at the University of California, and then at Davis, helped clarify the anatomical foundations of language.

Type	Spontaneous speech	Repetition of words	Language comprehension	Finding words
Broca's aphasia	abnormal	abnormal	normal	impaired
Wernicke's aphasia	fluent (at times logorrhea, paraphasia, neologisms)	abnormal	impaired	impaired
Conduction aphasia	fluent, but paraphasic	markedly impaired	normal	abnormal, paraphasic
Global aphasia	abnormal	abnormal	abnormal	abnormal
Anomic aphasia	fluent	normal, but anomic	normal	impaired
Achromatic aphasia	fluent	normal, but anomic	normal	impaired
Motor transcortical aphasia	abnormal	normal	normal	abnormal
Sensory transcortical aphasia	fluent	fluent	abnormal	abnormal
Subcortical aphasia	fluent	normal	abnormal (transient)	abnormal (transient)

Table.1 : Main characteristics of the different forms of aphasia.

V-1 Broca's aphasia

The syndrome known as Broca's aphasia is also referred to as motor or non-fluent because the patient suffering from this syndrome has difficulty speaking, even if he understands written or spoken language.
Individuals with Broca's aphasia have trouble finding their words and often stop while talking to find them. The inability to find the right word is called anomia (literally the lack of words). Curiously, Broca's aphasia can say a number of common things, such as the day of the week, almost without hesitation. The characteristic feature of Broca's aphasia is telegraphic-style speech, which mainly uses words that have content (nouns, verbs and adjectives with specific content in the sentence). In the jargon used to describe aphasia disturbances, the inability to construct grammatically correct sentences is called agrammatism. The problem is not the sound, but whether or not the word is a noun. Broca's aphasic has difficulty repeating the things he hears, while being more comfortable with familiar words like "book" or "nose." Sometimes he uses one sound or word for another. These are paraphasic errors. Unlike the speaking difficulties observed in Broca's aphasia, comprehension remains generally good.
Alterations in language articulation represent the most obvious aspect of Broca's aphasia. For this reason, it is believed that the disorder is associated with the motor aspect of language function. The aphasic understands words, but cannot pronounce them easily. Although Broca's aphasia has more difficulty with language than other aphasia, several facts suggest that there is something else to this syndrome. Understanding is generally well preserved, but the use of trick questions has shown that deficits can exist.
Wernicke suggested that the injured area in Broca's aphasia contains the acquired information to control the fine motor processes that articulate the sound of a word. This idea is attractive when we know that Broca's area is located near the part of the motor cortex that controls the mouth and lips. Wernicke's theory still has adherents, but there is also another way of looking at things. For example, the difference between the ability of the aphasic to use words that have content, and that to use words that have a function, suggests that Broca's area and the nearby cortex are specifically involved in constructing grammatically correct sentences.

V-2 Wernicke's aphasia

The syndrome observed by Wernicke is very different from Broca's. He notes that upper temporal lesions can cause aphasia, and he postulates that there are actually two types of aphasia: Broca's aphasia, characterized by language disorders while comprehension is fairly well preserved, and Wernicke's aphasia, characterized by fluent and voluble but incomprehensible language.Because of the flood of incomprehensible words, it is difficult to know whether Wernicke's aphasia understands what he hears or what he reads. Curiously, Wernicke's aphasic doesn't seem troubled by the incessant noise of his speech and that of others, even though he probably doesn't understand either. To check the patient's level of understanding, a non-verbal method is used. For example, the patient is asked to place object A on top of object B. The results obtained with questions and orders of this kind quickly show that Wernicke's aphasic does not understand what is being asked of him, unlike Broca's aphasia. The idea is then that Wernicke's area is a higher area of sound recognition, just as the inferotemporal cortex is a higher area of visual recognition. The deficits in sound recognition would account for the lack of understanding of others of Wernicke's aphasia. However, the lesion of Wernicke's area is not only associated with the strangeness of speech: the discourse observed in Wernicke's aphasia suggests that Broca's area and the system responsible for articulating words do not control their content.

V- 3 Conduction aphasia

The value of a model is not only related to its ability to report on previous observations but also to its ability to predict. Based on his observations that different forms of aphasia result from lesions of cortical areas located in the frontal cortex and in the superior temporal cortex, Wernicke predicted that there is a particular form of aphasia resulting from the lesion that interrupts the connection between Wernicke's area and Broca's area while preserving the integrity of these two areas. This particular aphasia would be due to a lesion of the fibers of the arcuate bundle, according to the model of WernickeGeschwind. In reality, these disconnection lesions normally affect the parietal cortex in addition to the arcuate bundle, but Broca's area and Wernicke's area are spared.
So Wernicke's prediction turned out to be correct. Aphasia following this type of lesions exists, and is called conduction aphasia. As predicted by the model based on the preservation of the Wernicke and Broca areas, understanding is good and language is fluid. The patient's oral expression is not affected. Conduction aphasia is essentially characterized by disorders in repetition tests: in response to the pronunciation of a few words, the patient must repeat what he hears. In this case, repetition results in poor performance punctuated by word transformation, omission of words, and paraphasic errors. Performance is generally better with short names and common expressions, but worse when it comes to words that have a function, polysyllabic words, or meaningless sounds. Curiously, the subject with conduction aphasia understands what he or she reads aloud, even though what he or she says contains many paraphasic errors. This corresponds to the idea that comprehension is preserved, and that deficits occur between the regions of language and comprehension. (Saffran Eleanor.M, 2000)**9**

VI- Aphasia and language: Wernicke-Geschwind model

Wernicke, after introducing what is known as Wernicke's aphasia as a result of observations, proposed a model of language processes in the brain. Norman Geschwind of Boston University developed this model, known today as the Wernicke-Geschwind model. The key anatomical elements of these processes are represented by Broca's area, Wernicke's area, the arcuate bundle (a set of axons connecting the two cortical regions) and the angular gyrus. The model also includes sensory and motor areas associated with listening and emitting language. Let's try to understand what this model means, using two tasks.

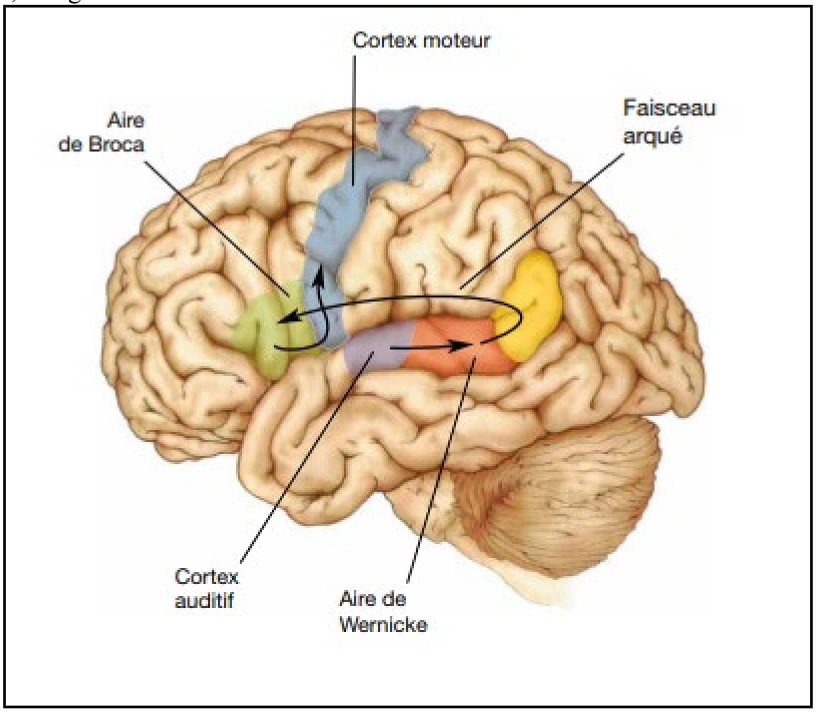

Figure .3 – Representation of the neural circuit involved in the process of repeating heard words, according to the Wernicke-Geschwind model.

The first task is simply the repetition of words heard (Figure.2). When the sounds of articulated words reach the ear, the auditory system analyzes the sounds and then sends messages to the auditory cortex. According to the model, sounds are not received as meaningful words until they are decoded in Wernicke's area. For a person to be able to repeat words, the decoded signal must be transferred through the arched beam from Wernicke's area to Broca's area. In Broca's area, words are coded to plan the movements of the muscles that condition language. Commands are transmitted from Broca's area to the motor cortical areas that control the movement of the lips, tongue, larynx, etc.
The second task is to read aloud a written text (Figure «3). In this case, the information is processed by the visual system, in the striate cortex and the higher visual cortical areas.

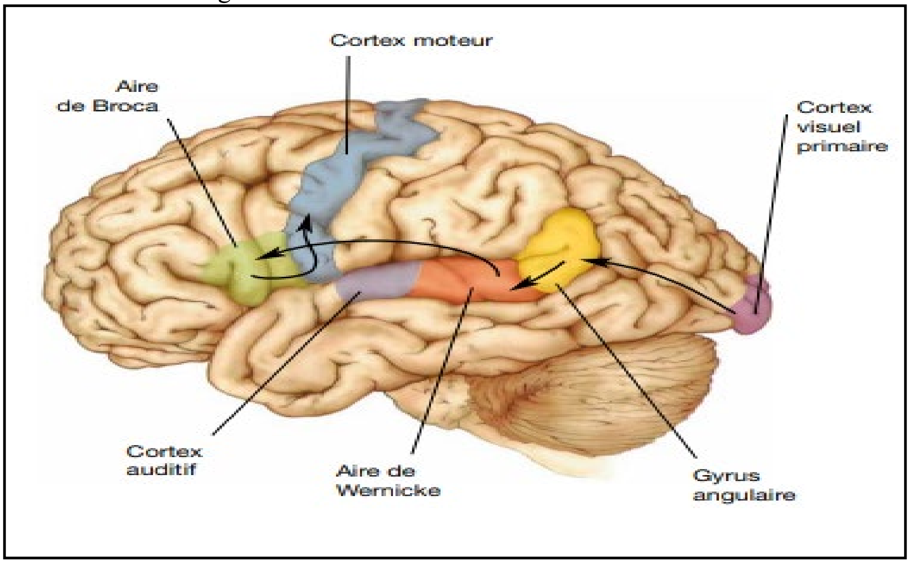

Figure.4 – Representation of the circuit involved in the process of repetition aloud of written words, according to the Wernicke-Gerschwind model.

Visual messages are then transmitted to the angular gyrus, at the junction of the occipital, parietal, and temporal lobes. It is imagined that message processing takes place in the cortex of the angular gyrus, and the transmitted message induces activity in Wernicke's area that would correspond to spoken and unwritten language. From there, the mode of transmission is the same as in the example of the first task: from Wernicke's area, to Broca's area, then to the motor cortex.
This model brings simple explanation on the elements-keys of the aphasia of Broca and that of Wernicke. Language is seriously affected by damage to Broca's area because the correct messages are no longer transmitted to the motor cortex. On the other hand, comprehension is relatively preserved because Wernicke's area is not affected. In contrast, understanding is severely impaired by damage to Wernicke's area because it is the site of conversion of sounds into words. On the other hand, the ability to speak is not affected by the fact that Broca's area still controls the movements of the muscles that allow language.
In fact, visual information is transmitted from the visual cortex to Broca's area, bypassing the angular gyrus. One of the risks inherent in all models is to give too much importance to a given cortical area, for a given function. It has recently been discovered that the severity of Broca's and Wernicke's aphasia depends on the extent of the cortex affected by the lesion, outside the Wernicke and Broca areas. On the other hand, lesions of subcortical structures such as those of the thalamus and caudate nucleus, which are not represented in the model, also have an influence on aphasia. As a result, language deficits following the surgical removal of parts of the cortex are more benign than those following a stroke, which damages both cortical and subcortical structures.
In the second half of the twentieth century, many models were developed to try to account for the complexity of language processing by the brain and the limitations of the Wernicke-Geschwind model. Much like the parallel processing of visual information pathways, these models also highlight the possibility of multiple processing by the brain of different aspects of language by parallel but interconnected pathways (Fig.4). (Norman Geschwind ,1979)6

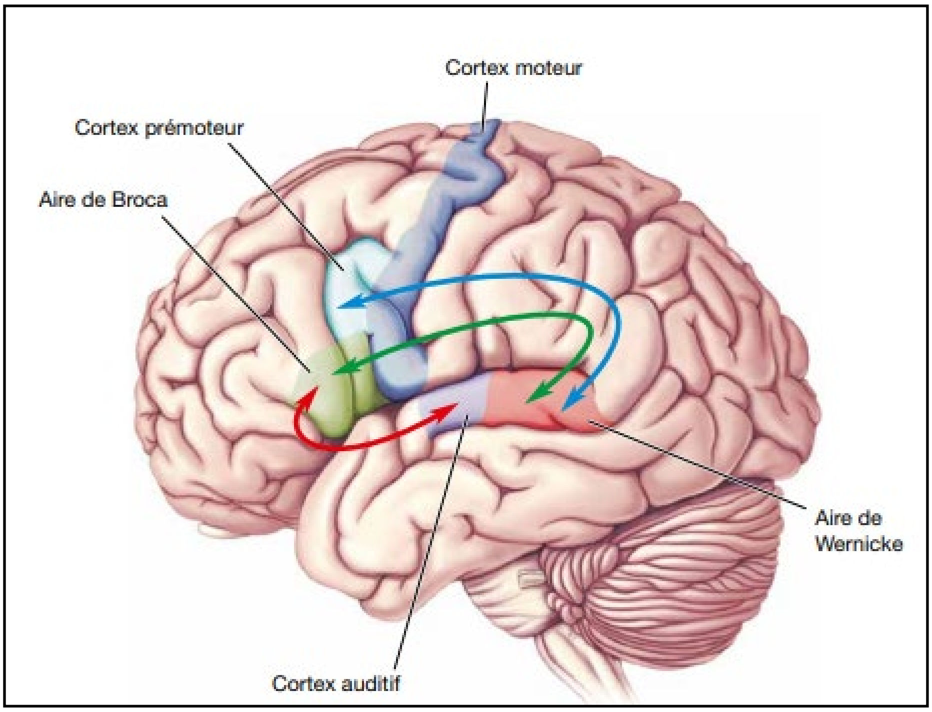

Figure 5 – Parallel processing of language-related information.

The most recent models of language-related processes highlight the existence of several systems acting in parallel, like the dorsal and ventral systems described for the processing of visual information. The model shown here has two dorsal pathways and a ventral component. Note that, contrary to what the Wernicke-Geshwind model postulates, the language in this case is not based on a simple anatomical link between Wernicke's area and Broca's area through the arcuate bundle. One of the dorsal pathways (in blue) connects the superior temporal gyrus (Wernicke's area and auditory areas) with the premotor cortex, and is believed to be involved in language production and word repetition. The other dorsal pathway (in green) connects the superior temporal gyrus with Broca's area, and is more likely to be involved in the complex syntactic structure of sentences, i.e. the analysis of words and their placement according to grammatical rules. The ventral system (in red) uses speech sounds to extract their meaning. (Figure 2), (Berwick Robert C & al, (2013)**2**

It is both sad and fascinating to observe the diversity of aphasia following a stroke. Although these syndromes often challenge all patterns, each of them represents a key to understanding language processes. (Table 2) reports the characteristics of a few other types of aphasia.

VII- Aphasia of bilingual and deaf people

The case study of aphasia occurring in bilinguals and the deaf provides some fascinating insights into the mechanisms of language. Take the case of a person who speaks two languages and suffers from a stroke: does aphasia affect one of the two languages, or both, in the same way? The answer depends on several factors, including the order in which the languages were learned, the ease of expression in each of the two languages, and the language used most recently. It is difficult to predict the consequences of a stroke, but it appears that the language learned in childhood and the most common, is less affected. If the person has learned both languages at the same time with the same ease of expression, the lesion will probably affect both languages in the same way. If the languages were learned at different times, one of the languages is likely to be more affected than the other. It is thus possible to think that the second language uses different populations of neurons, although nested, with those of the first.

The study of language disturbances in deaf people and/or those who use sign language shows that there is a certain unity of language processes in the brain. Sign language uses hand gestures to express all the ideas and emotions that are expressed through oral language. In subjects who use sign language, lesions of the left hemisphere result in language deficits comparable to those observed in verbal aphasia. In some cases close to Broca's aphasia, comprehension is preserved, but the ability to "speak" with sign language is severely impaired while hand movements are not affected (meaning it is not a motor control problem). Rather, the deficit concerns the use of hands in language expression.

There is also a manifestation of Wernicke's aphasia in sign language aphasia: the patient uses the signs with ease, but often makes mistakes, while having difficulty understanding the gestures of others. The rare case of a man whose parents were deaf and who had learned both sign and word languages was carefully studied.

Following a stroke in the left hemisphere, this man had global aphasia, but his condition improved significantly over time. The study of this case allows an important observation: he recovered his faculty of expression in both languages at the same time, as if the two brain areas concerned were intertwined. Thus, there are probably aphasias of sign language comparable to aphasia of oral expression, but it also seems that aphasia of signs and aphasia of speech are caused by lesions of the left hemisphere with slightly different locations.(Ayse Pinar Saygin & Fared Dick (2003)**1**

VIII- Asymmetric language processing by the cerebral hemispheres

Damage to parts of the brain leads to different forms of aphasia. As Broca's early work indicates, language is not treated in the same way in both hemispheres. The most interesting and fascinating illustration of the differential functional activity of the two hemispheres in language is given by a model called split-brain, in which the hemispheres are surgically repaired for therapeutic reasons. Communication between the cerebral hemispheres is made by several bundles of axons or commissures. The largest is the large cerebral commissure, also called corpus callosum (Fig. 5). The corpus callosum is composed of about 200 million axons, which pass from one hemisphere to another. Such a cluster of fibers must surely have an important function, but curiously, it was not until 1950 that the role of the corpus callosum was demonstrated. (Norman Geschwind, 1968)5

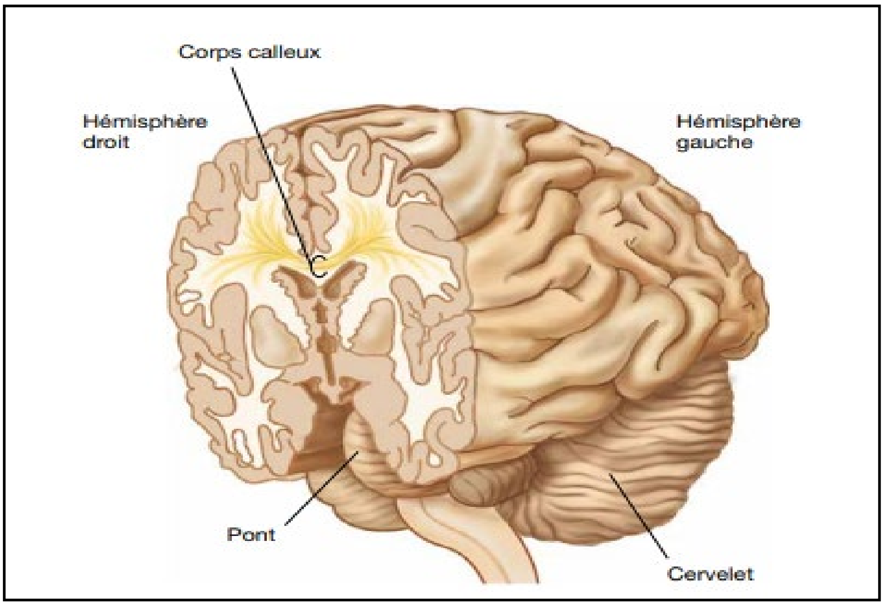

Figure 6 – Corpus callosum. The corpus callosum represents a bundle of axons involved in interhemispheric communication.

In a recent study by Kathleen Baynes, Michael Gazzaniga, and their collaborators at the University of California, Davis, it is suggested that the right hemisphere can sometimes contribute to writing, even though it is not involved in language. In most people, reading, speaking and writing are functions controlled by the left hemisphere. The study of a split-brain patient known as VJ shows that this is not entirely accurate. In this case, the words were “addressed” successively to the left hemisphere and to the right hemisphere. Words thus addressed to the left hemisphere could be rendered in spoken form, but not in writing. In contrast, those addressed to the right hemisphere could be written but not named. Although it is possible to object that this was a pathological situation, the case of this VJ patient nevertheless remains particularly interesting, indicating that all aspects of language are not necessarily confined to a single system located in a in a single hemisphere.

These results also prove that the right hemisphere understands complex images, despite its inability to express them. In another experiment, a series of images is presented to a patient in her left visual field, and one of the images is a photo of a nude. Asked what she sees, the patient says "nothing", but begins to laugh. She explains that she doesn't know why she's laughing, and that maybe it's because of the machine used for the experiment.

In addition, the right hemisphere seems to have better abilities than the left hemisphere in some areas. For example, the patients analyzed are all right-handed, and therefore their left hemisphere is preponderant for drawing; But their left hand controlled by the right hemisphere is more agile at drawing or copying images with a three-dimensional perspective. Patients are also better able to find complex puzzles with their left hand. Finally, it is also said that the right hemisphere would better perceive the nuances of sound.

In some of the split-brain patient studies, both hemispheres triggered seemingly conflicting behaviors, presumably because they analyzed the situation differently. In one of these studies, a patient was asked to assemble pieces of a puzzle complex enough to reproduce a drawing. . The instruction was that he performs this task using only the right hand, that is to say by mobilizing the left hemisphere which is not the best to perform this type of task. While the right hand struggled to assemble the elements, the left hand, which had more ease (bringing into play the right hemisphere), inevitably took over to carry out this work. Only the instruction given by the experimenter was able to prevent the left hand from contributing to the resolution of the puzzle. Another patient examined by Gazzaniga was trying to pull down his pants with one hand, while the other pulled him up. These bizarre behaviors illustrated the fact that there are two independent brains controlling both sides of the body.

The results of these split-brain studies demonstrate that the two hemispheres can function as two independent brains, and that they have different abilities vis-à-vis language. There is certainly a dominance of the left hemisphere in language, but the right hemisphere also has a certain ability to apprehend language. It should not be forgotten that split-brain experiments test functional differences between hemispheres. It is then possible to imagine that, in the normal brain, the activity of the two hemispheres is synergistic via the fibers of the corpus callosum, both for language and for other functions **(**Kathleen Baynes & Michel Gazzaniga ,1988)**4**

IX- Anatomical hemispheric asymmetry and language

Anatomical hemispheric asymmetry and language Cerebral asymmetries were already described in the 19th century. For example, it has been noted that the Sylvian fissure is longer and shallower on the left side of the hemisphere than on the right side (Fig 6). But it was only more recently, in the 1960s, that the idea that there were cortical asymmetries was really accepted, and that we began to ask questions about their functional importance. The astonishing asymmetry demonstrated in the control of language with the Wada procedure raises the question of anatomical differences likely to exist between the two hemispheres. The first serious quantitative data showing differences between the two hemispheres are due to the work of Geschwind and his colleague Walter Levitsky. The first observations were made on post-mortem brains and more recently by magnetic resonance imaging (MRI), which makes it possible to study the activity of the living brain.

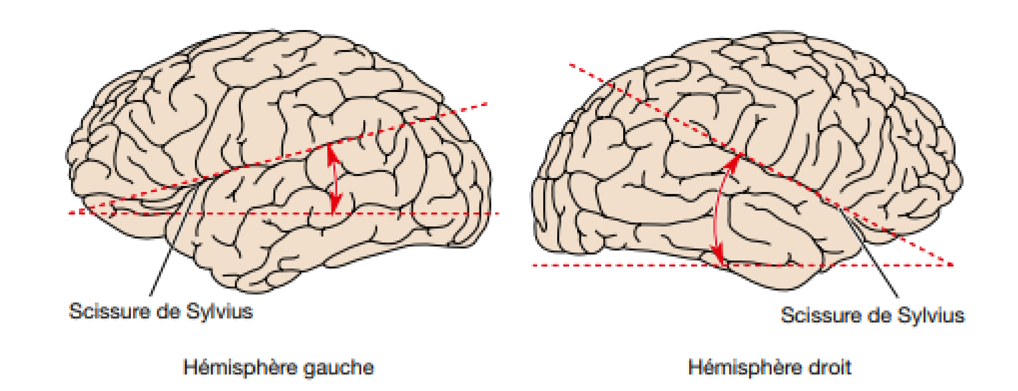

Figure 7 – Sylvius split asymmetry.

In most right-handed people, the Sylvius split of the left hemisphere is longer and less inclined than the split of the right hemisphere, (Geschwind, 1979).

The most significant difference is observed in the temporal planum on the upper surface of the temporal lobe (Fig 7). With the anatomical study of 100 brains, Geschwind and Levitsky showed that the temporal planum was more developed on the left in 65% of brains, and more developed on the right in only 10% of the cases studied. In some brains, the area was more than five times more developed on the left than on the right. Interestingly, this difference is already detected in the fetal brain, suggesting that it is not the consequence of the use of the left hemisphere in relation to language during development. In fact, in great apes too, the temporal planum is frequently more developed on the left. It is then possible to imagine that if the temporal planum is involved in language, the left hemisphere has become preponderant in language due to a pre-existing anatomical difference. Other studies have shown that part of Broca's area also has a propensity to be more extensive in the left hemisphere. If this is the case, then it is possible to ask whether these larger areas in the left hemisphere confer the dominance of this hemisphere in the production of language?

More recent work has used magnetic resonance imaging (MRI) in healthy subjects to determine cortical gray matter volume, in an attempt to correlate brain anatomy, interhemispheric asymmetries and hemispheric dominance in language. One of the difficulties of these studies, however, was to find enough subjects with right-hemisphere dominance for language. Some of the areas associated with language, whether Broca's area, the temporal planum, or the insula, are generally larger in the left hemisphere compared to the right hemisphere, and this is true in all subjects, whether they exhibit left or right dominance for language. The big question then is whether left or right hemispheric dominance can be determined simply from measuring the relative extent of language areas in the left hemisphere, reduced to the extent of the same areas in the right hemisphere. Thus it is possible to imagine that for left-dominated persons, the extent of one or more areas of language is much greater than that of the same areas of the right hemisphere, and that in the opposite case where it is the right hemisphere that dominates, the difference in the extent of these areas is much less obvious. or even larger in the right hemisphere compared to the left.

The results are contradictory regarding the correlation between the surface of the temporal planum of the two hemispheres, and the determination of the dominant hemisphere for language. Data have also been obtained on the same issue, now with regard to the extent of Broca's area.

To put it simply, it seems that there is a correlation between differences in the extent of Broca's and temporal planum areas between the two hemispheres and hemispheric dominance with respect to language, but that this correlation is not significant enough to predict hemispheric dominance simply from these surface measurements. The brain area that appears at this stage to have the best correlation, and therefore the best predictive value on hemispheric dominance,

happens to be the insula, a region of the cortex present in the lateral sulcus, located between the temporal lobe and the parietal lobe (Fig 8). Although the insula has long been proposed as a contributor to language, it is nevertheless true that the existence of this correlation between its size and hemispheric dominance is somewhat surprising, given the lack of studies devoted to the involvement of this region in language-related functions. In fact, the insula has been studied so far in relation to its involvement in other brain functions, including taste perception or emotions. Further work seems necessary before reaching more definitive conclusions on the subject of the relationship between its surface and hemispheric dominance relative to language.
Manual preference is also a form of functional asymmetry, much better known and more evident than in the case of language. More than 90% of subjects are right-handed, and they are usually quite clumsy with their left hand. This somehow shows that the left hemisphere plays a prominent role in the subtle processes of motor control. Can we then say that this activity is related to language? The answer to this question is not known, but it should be noted that humans are different from other primates in terms of manual preference as well as language. However, if in many species animals show a marked manual preference like humans, contrary to what is observed in the human species, in these animals the number of left-handed and right-handed is roughly equivalent.

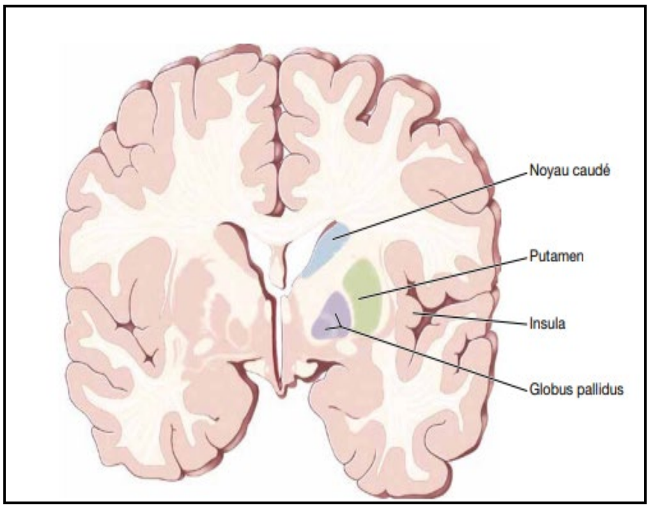

Figure 8 - represents Insula.

X- Conclusion

The appearance of language was one of the critical stages of human evolution. Communication between individuals is such a fundamental element of our societies that it is difficult to imagine a life without language. It is thus estimated that the appearance of language is relatively recent, around 100,000 years ago. While animals use many sounds and behaviors to communicate, none of them achieve the extreme sophistication and flexibility of human language. Current knowledge on language acquisition has been acquired on models using songbirds or even non-human primates. However, to access the language mechanisms of the human brain, it is necessary to analyze these processes in humans. In this context, the experimental approach has been largely limited to behavioral studies concerning the acquisition and functioning of language, the analysis of the consequences of lesions, the effects of brain stimulation on language, and functional imaging studies in PET or fMRI. Thus, even if one can consider that the number of approaches to this problem is rather low, the fact remains that considerable progress has been made in the knowledge of the mechanisms of language. More specifically, in accordance with what is already known about sensory and motor areas, the neuronal bases of language can be approached and already largely understood. The pattern that emerges highlights the role of Broca's area located near the motor areas and involved in speech production, and that of Wernicke's area, closer to the auditory cortex and associated with language comprehension. These considerations, although overall rather old, are still perfectly useful in the clinic today.
More recent work, however, illustrates the fact that language mechanisms are much more complex than initially proposed and involve larger brain regions than those envisaged by the WernickeGeshwind model. These data are the result of studies using functional brain imaging and brain stimulation, which illustrate the contribution of much larger regions than previously defined, including in both hemispheres.

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