ALLISON ANIMATION

George Page (V/O):

And just ahead of that ribbon of brain, another whose job is to orchestrate movement -- sending commands to the spinal cord, then along the arm to the hand, telling it to change gears.

STOCK FOOTAGE
Renault
Race Car Driver

ALLISON ANIMATION

George Page (V/O):

In front of it all is the driver's frontal lobe -- the part of his thinking planning brain -- that bundle of tissue which provides him with a strategy to win the race.

STOCK FOOTAGE
Renault
Race Car Driver

ALLISON ANIMATION
Whole Brain Model
Crystal Brain

George Page (V/O):

No single area of the brain can win the race by itself. No single tissue can function without the help of the rest of the brain. The brainstem, the midbrain, and all those regions along the surface are in constant contact with each other -- always active -- even when the body sleeps.

CAT SCAN PHOTOGRAPHS
New York Hospital

George Page (V/O):

How do we know all this? Thanks, in part, to the fantastic tools that the modern-day brain detective uses to look inside the brain. The CAT scan penetrates the skull to x-ray the brain's structure, showing the location of actual brain tissue.

PET SCAN PHOTOGRAPH
NIH

George Page (V/O):

The PET scan forms still pictures of the brain's activity. Its colors show which areas are most and least active.

EEG SEQUENCE MS WOMAN IN BED	**George Page (V/O):** One of the newest tools for looking at the brain is based on an old and established technology
BRAIN RECORDINGS	the EEG, or electroencephalogram -- in which the brain's electrical activity is recorded from sites on the scalp.
JESSE SALB'S EEG TOPOGRAPHIC MAP SEQUENCE	**George Page (V/O):** The new invention is a computer program. It translates those electrical signals onto an actual map of the brain. The squiggles on paper are transformed into colors...
CU JANET CRISTENFELD	**Jesse Salb (V/O):** Janet, now you're going to be looking
CU JESSE SALB	**Jesse Salb (O/C):** at a checkerboard pattern repetitively flashed on this TV screen.
MS JANET/SCREEN	**Jesse Salb (V/O):** I want you to keep your eyes focused on the center of the screen. **Janet (O/C):** O.K.
SCREEN W/ JANET'S IMAGE CU JANET EYEBALLS CU JESSE SALB SCREEN &JANET CU EYE SCREEN & JANET	**George Page (V/O):** With this device we can see the electrical changes of a brain at work. The bright colors represent positive electrical charges. Jesse Salb, the inventor, is watching the brain process a visual image. The signal from the screen flashes into the eyes, and then rushes through the brain like this...
JESSE SALB'S EEG TOPOGRAPHIC MAP SEQUENCE - Vision	**George Page (V/O):** Slowed down, we can watch vision deciphered, first at the back of the brain, in a burst of yellow and red. About 3/10 of a second later, we can observe activity at the

JESSE SALB'S EEG TOPOGRAPHIC cont'd

top of her brain as she realizes what she's just seen.

DR. ERIN BIGLER'S 3D MRI EXAMPLES
4 QUADRANT VISUAL

George Page (V/O):
One of the most exciting and recent developments in studying the functions of the normal and injured brain involves combining neuroimaging techniques, specifically magnetic resonance imaging or MRI, with computer technology that allows the images to be reconstructed into three dimensional pictures.

George Page (V/O):
One of the pioneers in using this new method is Dr. Erin Bigler at Brigham Young University.

DR. ERIN BIGLER
Brigham Young University

Dr. Bigler (O/C):
Current magnetic resonance imaging technology allows us to acquire the images of the brain three dimensionally. This permits a sectioning of the brain at any level or focusing on any region that we would like to focus on. It's a marvelous technology that allows us to view the brain in any plane. It's very easy to see what I'm talking about by looking at this image that we have on the screen right now. I will set this into motion and it will become evident what we can do.

CU 3D IMAGE

Dr. Bigler (V/O):
The head will move around, tilt back, and we will now expose the brain. We see the right hemisphere on the right hand side, left hemisphere on the left hand side. The image will now come back to the top of the skull, and the head will rotate down, now move, look at the lateral surface of the brain and then make these cuts all the way through.

3D IMAGE OF INJURED BRAIN

George Page (V/O):
We can use Dr. Bigler's techniques to help us investigate different pathologic states of the brain. For example, in this man who had a severe brain injury after a 30 foot fall from a scaffolding, we can demonstrate areas of brain damage as shown in green...

enlargement of the internal cavities as shown in brown...

and combine these images to help us better understand the effects of brain injury on behavior.

DR. ERIN BIGLER

Dr. Bigler (O/C):
Prior to the advent of contemporary neuroimaging methods, we had no way of looking at the brain of a living individual

short of operating on the head. Now we can look at all levels of brain and brain function using these contemporary neuroimaging methods. Great advancements have been made in diagnosing neurologic disorders and we hope and anticipate that these methods will allow us to discover better treatments and to understand neurologic disease and disorder better.

Brain II - 2nd Edition

HORMONES AND SEXUAL DEVELOPMENT:MODULE 2

JAPANESE FOOTAGE-NHK

George Page (V/O):
We now know there are important differences between the brains of the two basic groups that comprise humankind, males and females.

SWEDISH STOCK FOOTAGE
Generis People
"Miracle of Life"

George Page (V/O):
The question of even minor, statistical differences between men and women is a highly charged issue. Both sexes have strong feelings about the very idea and the evidence is only beginning to emerge. Nevertheless, there are statistical differences. They exist for example in the senses: smell, hearing, touch, as well as in hand preference. It's now thought that hand preference is affected by sex hormones during brain development. About 10% of males are left-handed, compared to only 4% of females.

UN FOOTAGE
Handedness Montage

George Page (V/O):
Left handers actually respond differently to the world. They include a higher percentage of artists, architects,

WW FILMS STOCK FOOTAGE
Tennis

George Page (V/O):
and athletes. And they suffer more learning disabilities, like stuttering, autism, and dyslexia.

SWEDISH STOCK FOOTAGE
"Miracle of Life"

George Page (V/O):
How do left-handers develop differently and what is the effect of the sex hormones? Every male fetus receives jolts of testosterone from the testes. Very possibly, left-handers receive more.

TESTOSTERONE CRYSTAL

This is testosterone. Does the extra dose slow brain development in the left hemisphere--shifting males from a right-handed pattern to a left-handed one? We don't know, but we do have evidence of the power of sex hormones to shape the brain and body.

INT. DR. DIAMOND'S LAB
Univ. of CA, Berkeley

George Page (V/O):
Rats, like humans, have divided brains. Using special techniques to freeze, slice, and measure the cortex, Professor Marian Diamond at the University of

INT. DR. DIAMOND'S LAB cont'd
DR. DIAMOND

George Page (V/O):
California at Berkeley has found structural differences between the two hemispheres. She has also found sex differences. ~~In female brains, the hemisphere thickness is symmetrical. In male~~

is thicker.

brains, the right hemisphere
To find out whether she could reverse this male female pattern, Diamond manipulated the early hormonal environment.

DR. DIAMOND

Dr. Diamond (V/O):
We decided to take the ovaries out

VIDIFONT 8
Dr. Diamond
University of CA
Berkeley

Dr. Diamond (O/C):
of the rats, when they were first born and then look at the right-left differences when the rats were young adults, and we found that the pattern had switched. Instead of being symmetrical, we found a larger right hemisphere in the females without ovaries--
very similar to the pattern in
the males, especially in the visual-spatial area.

SECTIONING BRAINS

George Page (V/O):
Diamond also removed the testes of the males at birth, and found that the front two thirds of the brain switched, the left hemisphere being thicker than the right.
In other experiments, rats were exposed to three different

INT. DR. DIAMOND'S LAB cont'd

George Page (V/O):
environments: a barren impoverished environment, a standard colony, and an enriched environment, filled with toys and social contact. Could these environments actually have an effect on the size and shape of the cortex?

RATS

Dr. Diamond (V/O):
The results show that the enriched rat's cortex was thicker than that of the standard colony rat and the impoverished rat's cortex was actually thinner than that of the standard colony rat. So in essence, with enrichment, the brain grows, and with impoverishment, it decreases in size, a basic use it or lose it paradigm.

INT. DR. DIAMOND'S OFFICE
DR. DIAMOND

Dr. Diamond (O/C):
We find sex differences in the animals that have been exposed to the enriched environment. In the males, we find greater changes in their visual spatial areas. In the females, we find greater changes in their general sensory cortex.

DR. DIAMOND DRAWING

George Page (V/O):
By measuring the thickness of the cortex, Dr. Diamond can judge the effects of these environments. She has two consistent findings: experience can change the cortex at any age; and there are sex differences in how the cortex responds.

Dr. Diamond (V/O):
We don't have too much hesitation in extrapolating our findings from rats to humans, because rat and human brains are made up of the same basic constituents, and with time, many of the findings in rats are duplicated in humans.

George Page (V/O):
Recent evidence has shown differences in the anatomy of the human brain with the right and left hemispheres in the male being more asymmetrical and the right and left hemispheres in the female being more symmetrical. These results are similar to those found in the rat, but the human cortical changes through a life time have not yet been identified as we have shown in the rat.

Brain II - 2nd Edition

Module 3 Gender Development and Social Influences

VIDIFONT 9
Dr. Caroline Smith
University of Sussex

George Page (V\O):
Gender development is influenced by both biological and environmental factors. Research by Caroline Smith is studying the effects of how we treat children children on gender development. She asks mothers to play with children they have never met before.

Caroline Smith (O\C):
He's six months old so he can't really sit up. If you put him down on the floor, put a hand behind him to support him.

BBC STOCK FOOTAGE
"Fight to be Male"

Carolyn Smith (O/C) cont'd:

But that's it. You can do what you li where you like for ten minutes.

George Page (V/O):

Smith is analyzing the difference between mothers' reactions to girls and to boys.

MOTHER/BABY

Mother (O/C):

Hello. There. What would you like to see? What would you like to see? Would you like to see that? Would you just like to say hello for a minute? That's a funny noise isn't it.

George Page (V/O):

The toys the mothers offer the babies are influenced by the child's sex.

Mother (O/C):

One, two, three, would you like to hold this for a minute? That's a nice smile? Can you crawl? Are you going to start to crawl?

George Page (V/O):

Boys are encouraged to be active -- to explore their environment.

Mother (O/C):

There what can you see? There's a ball. There. What can you see?

BBC STOCK FOOTAGE
"Fight to be Male"

Mother (O/C):

There's a ball. There. That's all right. You're getting there. Thats right you got it.

George Page (V/O):

Buth, the children are sometimes disguised. Jamie is a boy, but for the next person he'll appear to be a girl.

Mother (O/C):

Funny being a girl isn't it?

George Page (V/O):

His mother will hand him over as Jane.

Mother (O/C):

Very pretty...

Here is Jane.

MOTHER/BABY

George Page (V/O):

Smith finds that we talk more to girls. We often tell them they are pretty and we encourage them to be less active then boys. So we do treat boys and girls differently.

We offer them different experiences, encourage different abilities. But the question remains: Are the different characteristics of males and

BBC STOCK FOOTAGE

George Page (V\O):
females mainly the result of experience? Or are they built into the two-sided brain?

FRENCH FOOTAGE
Georges Masraff-Chef

George Page (V\O):
The answer is probably both. Yet this knowledge tells us practically nothing about individual men and women. Our specialized two-sided brain insures that we vary in our tastes and talents, skills and abilities, needs and wants.

Brain I + II, 1st & 2nd Editions are same.

INTELLIGENCE AND CULTURE: MODULE 4

BBC HUMAN BRAIN FOOTAGE Show #2-Memory Aborigines AUSTRALIAN LANDSCAPE	George Page (V\O): The Aborigines of Australia have survived the trackless wastes of the continent for centuries. To do so, they have developed extraordinary visuospatial skills; a feature of the right hemisphere. Has the combination of experience and evolution changed the way they think? Aboriginal children do not perform as well as white children on conventional verbal tests. One psychologist, Judy Kearins, thought the tests might be ignoring the Aborigine's real skills.
SHOTS OF CHILDREN	Dr. Kearins (V\O): The children, I've found know a great deal more than most white Australian people. They take for granted that we possess most of the knowledge they have and we don't. They think that a sense of direction is built into everybody, for instance. And also the same thing applies to all their knowledge about the wildlife they were raised in. They don't really seem to think that any of their knowledge is special and it is very much so...

MEMORY GAME

George Page (V\O):
Dr. Kearins believes that Aboriginal children use their visual and spatial memories more than the white children. She invented a game to test her theory. The task--to remember the positions of a set of objects on a board.

MS DR. KEARINS

The man-made objects should be easier for verbal-oriented children to remember, because natural objects are not as easily described and remembered in words.

ABORIGINAL CHILDREN
PHILOMENA\GAME

Kearins used both natural And man-made objects.

Dr. Kearins (V\O):
All right open your eyes and see.

George Page (V\O):
The most difficult group of all to describe verbally: twelve stones.

CU PHILOMENA

Philomena has 30 seconds to memorize the positions of the stones. She can take as long as she likes... to put them back.

Dr. Kearins (O\C):
Good, that's lovely. Finished? Now, I tell you, they're almost all in the right places. That one's right, that one's right...that is, that is, that is...Those two should be swapped around, do you think so?

VIDIFONT 5
Dr. Judy Kearins
University of Western Australia

Dr. Kearins (O\C):
I've tested children between the ages of six something, and about 16 years and a bit now, and they always perform better than white Australian children and also the rate of, er, superiority, if you like, stays about the same. They perform at about the, er, about three years ahead of the white Australian children, so that an Aboriginal child of, er,

CU PHILOMENA

Dr. Kearins (V\O):
of, er, seven years about, would perform about as well as a ten year old white Australian child, not quite as well, but it's about a three year difference.

Dr. Kearins (V\O):
They also tend to perform these tasks in even ways in terms of tempo, they don't hurry and put a few back and then slow down,

Dr. Kearins (O\C):
they seem to perform at the same rate all the time, and they also don't mutter or mumble which a lot of white Australian children have done while they were viewing the tasks, er, thinking if it's to learn the names, hoping that would help them to remember

ENVIRONMENT SHOTS	Dr. Kearins (V\O): where the items went. George Page (V\O): The two groups of children used different strategies--and perhaps, different parts of their brains--to solve the puzzles.

Brain II script - 2ND Edition

Module 5: Split Brain
Time 7:44

ALLISON ANIMATION Head/Whole Brain/Neural Net	**George Page (V/O):** The cortex, the wrinkled outer layer of the brain orchestrates talents and skills. It's a network of nerve cells. Music, language, mathematics, problem solving and face recognition - all are activated here among the billions of neuronal connections.
ALLISON ANIMATION Split Brain	**George Page (V/O):** The two halves of the brain may look alike But they're not. They're asymmetrical. They don't have identical skills and abilities. Each side has its own way of knowing the world and processing information. By and large, each side controls the opposite side of the body.
ALLISON ANIMATION Hand Model	**George Page (V/O):** When you move your right hand, the left side of the brain is at work. When you move your left hand, the right hemisphere is in control. Most people have a dominant hand a sign of the brain's asymmetry
FRENCH FOOTAGE	**George Page (V/O):** Most mental functions, like language and spatial skills, are generally housed in one hemisphere or the other. This division of responsibility makes evolutionary sense.
ALLISON ANIMATION Corpus Callosum Model	**George Page (V/O):** Normally, both halves of the brain work in concert. A massive system of fibers, called the Corpus Callosum, carries impulses to and from each side.
BBC HUMAN BRAIN FOOTAGE Show #1 - Self Split Brain Operation	**George Page (V/O):** In the early 1960's, surgeons revived an old technique of cutting the Corpus Callosum to control massive seizures in some epileptics. The

BBC HUMAN BRAIN FOOTAGE cont'd	operation works. It also provides an opportunity to study the different properties of the two hemispheres.
FREEZE FRAME ON SURGEON	It is important to remember that all of these patients suffered from poorly controlled epilepsy, and so, some of the findings may reflect changes in brain organization secondary to the epilepsy.
EXT. VICKI WALKING	<u>George Page (V/O):</u> Vicki is a split-brain patient. Because of her
INT. KITCHEN	epilepsy, surgeons severed her corpus callosum. Now her right hemisphere can no longer communicate with her left.
INT. CLOSET	<u>Vicki (V/O):</u> I knew what I wanted to wear. I would open up my closet, get ready to take it out, my other hand would just take control. <u>Vicki (O/C):</u> It would reach in and get something that I wouldn't want at all and then I'd get frustrated and throw the one on the bed that I don't want. A lot of times, I can't even hang the stuff back up.
INT. KITCHEN LIGHTING OVEN	<u>George Page (V/O):</u> This antagonistic behavior between hands occurs between hands occurs only right after split brain surgery.
FREEZE FRAME ON COOKIES IN OVEN	Vicki actually does very well in her daily activities, even though her left hemisphere is disconnected from her right. It takes special testing to reveal the different processing styles of the two hemispheres. (from Brain I)

INT. DR. GAZZANIGA'S OFFICE

Cornell Medical Center

VICKI
DR. GAZZANIGA/ASSISTANT
VICKI

George Page (V/O):

Vicki is frequently tested at Cornell Medical Center by Dr. Michael Gazzaniga.

Dr. Gazzaniga (O/C):
Look right at the dot.

Vicki (O/C):
Okay.

George Page (V/O):
The tests are designed to send different kinds of information to each hemisphere.

Dr. Gazzaniga (V/O):
We're going to have you watch some pictures. After I flash them, I simply want you to describe them to me. Just name the picture you see.

BBC HUMAN BRAIN FOOTAGE cont'd	<u>Vicki (O/C):</u> Okay. <u>Dr. Gazzaniga (V/O):</u> So get ready and look right at the dot. Fixate the dot. Look at the dot. <u>Vicki (O/C):</u> Okay.
CU PICTURE FOOTBALL	<u>Vicki (O/C):</u> Football...
MS VICKI	
SHOE	<u>Vicki (O/C):</u> Shoe.
CU PICTURE WOMAN ON PHONE	
CU VICKI	<u>Vicki (O/C):</u> A woman...a person. <u>Dr. Gazzaniga (V/O):</u> What else? <u>Vicki (O/C):</u> A girl...that's all. <u>Dr. Gazzaniga (V/O):</u>
VICKI'S HAND WITH PEN	Okay. I'll tell you what.. open your eyes. Put the pen in your left hand. Write what she was doing, Close your eyes and just let your left hand go.
CU VICKI	<u>George Page (V/O):</u> Vicki's right hemisphere doesn't have the
CU WRITING	language to describe the whole picture. But, it can express itself through her left hand. <u>Dr. Gazzaniga (V/O):</u> Good. What did you write? <u>Vicki (O/C):</u>
CU TELEPHONE	Skipping rope? <u>Dr. Gazzaniga (V/O):</u> Huh? <u>Vicki (O/C):</u> Skipping rope? <u>Dr. Gazzaniga (V/O):</u> Skipping rope. No. Let me show you what you wrote.

CU VICKI	**Vicki (O/C):** Telephone **Dr. Gazzaniga (V/O):** Yeah. What was she doing? **Vicki (O/C):** Talking on the telephone. **Dr. Gazzaniga (V/O):** Remember that? **Vicki (O/C):** Yeah. **Dr. Gazzaniga (V/O):** Good. Perfect.
GRAPHIC: WOMAN ON PHONE	**George Page (V/O):** Vicki saw the picture on her left. It went to the left side of both eyes. The visual information then traveled to her right hemisphere. It understood the picture but could only say woman.
VICKI WITH GRAPHICS WHOLE BRAIN LEFT HALF SEARCHING FOR RIGHT WORD GRAPHIC-READS 'TELEPHONE'	**George Page (V/O):** Then she was instructed to write using her left hand. Her right hemisphere directed her hand to spell out the other feature of the picture. Dr. Gazzaniga asked what she had written. The left hemisphere tried to guess. It had not seen "telephone" so it searched for a word somehow associated with the image it had seen. When both hemispheres saw the written word, the left, which had heard the right say "woman", could now give a complete description: "woman on the phone".

BRAIN MODEL

Dr. Gazzaniga (V/O):
How about another one? You're doing just perfect. Oh this is a good one.

VICKI

GRAPHIC: LAP/LAUGH

Vicki (O/C):
Okay.
Laugh...mumble...like..I don't know.

VICKI

George Page (V/O):
Both hemispheres respond to the words. The left triggers her smile; the right makes her clap.

Dr. Gazzaniga (V/O):
So what did you see that time?

Vicki (O/C):
Laugh

George Page (V/O):
Both sides receive the command a the same time, but the left side can communicate its awareness.

Brain II - 2nd Edition

Module 6: Language and Speech:
Broca and Wernicke's Areas

ALLISON ANIMATION
Brain Model
Still brain visual

George Page (V/O):
While the whole brain normally participates in communication, most of what we think of as language depends on the left side of our brains. The area for language on the left side is more densely wired--and even structured differently than the same area on the right. In 1861, Paul Broca discovered the left hemisphere's role in language.

BBC HUMAN BRAIN FOOTAGE
Show #3-"Language"

INT. LAB
"Ta's" brain in jar

George Page (V/O):
This brain changed the course of neuroscience. It belonged to a stroke patient nicknamed "Ta." He was given that name because "TA" was all he could say. After Ta died, Paul Broca examined his brain. Because Ta could not speak, Broca concluded the damaged part of the left hemisphere was responsible for language. It's now called Broca's area. Ta's brain was recently rediscovered in a Paris Museum.

SCIENTISTS X-RAYING BRAIN
CAT SCAN PICTURE

Scientists x-rayed it with a CAT scan. The black area in the left hemisphere is where damage occurred. We now know that Broca was largely right: damage to Broca's area does disrupt language.

CHARLES LANDRY/DOG
EXT. BEACH

George Page (V/O):
Until his stroke, Charles Landry had a thriving legal practice. At age 45, a blood clot cut off circulation to part of his brain and put an end to his professional career.

INT. LANDRY' STUDY
CU LANDRY

At the heart of practicing law is a facility for language. Landry's stroke affected both his ability to understand language and his ability to express himself.

Charles Landry (O/C):
Contingent remained is...
er...is sell it, sign it, deliver it or anything...

Charles Landry (V/O):

er subject to a contingency...

Charles Landry (O/C):

Oh boy.

BBC HUMAN BRAIN SERIES
INT. DR. GESCHWIND'S OFFICE
CU DR. GESCHWIND
VIDIFONT 2
Norman Geschwind
Harvard Medical School

add "late" NG here

Dr. Geschwind (O/C):

When we talk about language difficulties we mean problems with either grammar or the choice of words and if you were listening to Dr. him, someone might say, well, his grammar is all right and even though he takes a long time to find the words, he tends to find them. His difficulties are really all mechanical ones. He's slow, he's got trouble getting going but, er, none of this is really language disturbance. I think that problem gets resolved very quickly when we start to examine his understanding of language.

MS D

Dr. Geschwind (O/C):

Do you ever have any trouble with what I say?

Charles Landry (O/C):

No.

Dr. Geschwind (O/C):

Understanding it?

Charles Landry (O/C):

No.

INT. DR. GESCHWIND'S OFFICE
CU LANDRY

Dr. Geschwind (V/O):

Now, suppose you wanted to communicate with a person

Dr. Geschwind (O/C):

who was in a distant city, what apparatus would you utilize?

Charles Landry (O/C):

Telephone.

Dr. Geschwind (O/C):

Very good. I deliberately made that a sort of curious sentence just to show how well you did. Let me ask you -- do dogs fly?

BBC HUMAN BRAIN FOOTAGE cont'd

Charles Landry (O/C):
No.

Dr. Geschwind (O/C):
How about this...Do submarines usually fly?

Charles Landry (O/C):
No.

Dr. Geschwind (O/C):
How about a zeppelin? Can a zepplin fly?

Charles Landry (O/C):
Yes.

Dr. Geschwind (O/C):
I couldn't make the question complicated enough in terms of the fanciness of the vocabulary to throw him off. He immediately understood. And yet, when I produce a sentence that most of us would have thought was as easy an English phrase as you could create, he failed totally.

CU DR. GESCHWIND

Dr. Geschwind (O/C):
Do you know what a leopard is?

Charles Landry (O/C):
Yes.

Dr. Geschwind (O/C):
Do you know what a lion is?

Charles Landry (V/O):
Yes.

Dr. Geschwind (O/C):
The leopard was killed by the lion.

CU LANDRY

Dr. Geschwind (V/O):
which animal died?

Charles Landry (O/C):
I don't know...ohhhh...

Dr. Geschwind (V/O):
That's hard, is it?

Charles Landry (O/C):
Ohh no, no...I don't know. What animal died...I don't know.

BBC HUMAN BRAIN FOOTAGE cont'd	Dr. Geschwind (V/O): You don't know what animal died?
	Charles Landry (O/C): Right
CU DR. GESCHWIND	Dr. Geschwind (O/C): Obviously, that's got to be an error in understanding the grammar. Now there's a very easy way to understand it, because if you think of those sentences with the grammatical words removed and try to figure out their meaning, you would have the same problem.
GRAPHIC: Leopard was killed by lion	George Page (V/O): Landry hears all the sounds of the grammatical words, but in his brain, the sentence is processed something like this. He understands only the nouns and verbs.
CU DR. GESCHWIND	Dr. Geschwind (O/C): This pattern of having this special kind of understanding difficulty which is confined almost exclusively to these little words, to these grammatical words and to the endings, is something that we find very frequently in the patient who has got damage to Broca's area...So the thing that is so

perplexing in Mr. Landry is that he doesn't have this difficulty in spontaneous speech; he doesn't have this difficulty in repetition; but when we come to the comprehension test, he has this difficulty in the most dramatic fashion.

George Page (V/O): Broca's discovery was important, but it wasn't long until other investigators discovered additional areas in the left hemisphere contributing to language...

BUST: CARL WERNICKE with BRAIN MODEL

George Page (V/O): In 1874, the German scientist, Carl Wernicke, identified a third language area in the left hemisphere. Broca's area, in front, plays a major role in speech production and grammar. The strip in the middle controls and coordinates movement. But Wernicke's area is involved both in the formation of what is said and in comprehension. When it is damaged, speech seems fluent but doesn't make sense. We now know how we process and repeat words. First, sound travels as nerve impulses to Wernicke's area where it is analyzed; to Broca's area where sounds are assembled into sequences and finally to the motor cortex, which directs movement and sends signals to the speech muscles.

EXT. LANDRY FAMILY ON BOAT

George Page (V/O): Charles Landry's brain damage has produced difficulties that are fairly typical of patients with damage to Broca's area. From patients like him, we have learned a great deal about how the left hemisphere decodes, processes and produces language.

Brain II - 2nd Edition

Module 7: Brain Anomaly and Plasticity: Hydrocephalus

ALLISON ANIMATION Head Model	George Page (V\O): Another way we're discovering how our most important organ works is by observing how it adjusts to serious injury. In certain cases, its power to heal itself is almost miraculous.
YORKSHIRE TELEVISION STOCK FOOTAGE Hydrocephalus CU HYDROCEPHALIC BABY'S HEAD	George Page (V\O): Take hydrocephalus-an often fatal abnormality of infancy, when the normal flow of spinal fluid out of the brain is blocked, and pressure builds up inside the skull.
INT. DR. LORBER'S OFFICE CU NORMAL BABY'S BRAIN	Dr. Lorber (V\O): In a normal brain of a baby, the ventricles are in a butterfly shaped structure.
VIDIFONT 7	Dr. Lorber (O\C): On this brain of a hydrocephalic child, from the outside
HYDROCEPHALIC BRAIN	Dr. Lorber (V\O): it looks roughly normal. It's not normal, but when you turn it around, these ventricles are enormously dilated and the brain is only about half a centimeter thick.
CU VALVE CHILD\DR.'S GOING INTO SURGERY OPERATION	George Page (V\O): In 1955, a valve and shunting procedure was developed that permitted the release of the fluid from the brain in a long bypass from the heart, for recirculation. Since then, the valve implant operation has saved the

lives of hundreds of thousands of hydrocephalic children. With no continuing trauma to their brain tissue, many have become normal. In a few remarkable cases, some like Sharon have done even better.

EXT. ENGLISH COUNTRYSIDE
SHARON WALKING

<u>Sharon's</u> <u>Mother</u> <u>(V\O):</u>
I always thought she was about average, but now I'm beginning to wonder if she's probably more than average. She got every exam that she took. She didn't fail anything.

<u>Sharon's</u> <u>Father</u> <u>(V\O):</u>
Even the English?

<u>Sharon's</u> <u>Mother</u> <u>(V\O):</u>
Yes, and English is the one that she's not too sure of. The chemistry,

MS SHARON'S PARENTS

she was the only girl to get a GC in that school and in biology she was the only one of two girls to get that GC.

INT. HOSPITAL

<u>George</u> <u>Page(V\O):</u>
How can Sharon possibly be above average? What does her brain look like? Could it have assumed a normal shape? Sharon's consulting pediatrician, Dr. John Lorber in Sheffield, England, tried to find out. Sharon underwent a CAT scan to reveal the interior structure of her brain. In the

CAT SCAN PHOTO
Normal Brain

normal brain, a CAT scan shows tissue completely filling the skull, with the shadow of the

SHARON IN CAT SCAN MACHINE

butterfly-shaped ventricles in the

SHARON'S CAT SCAN

center. But in Sharon's

scan, the image is extraordinarily different. The tissue of her brain is nearly flattened against the wall of her skull. How has she survived so well with such an distorted brain? Since a CAT scan cannot answer this question, Sharon was

INT. HOSPITAL IN DENMARK
Cerebral Blood Flow Scan

flown to Denmark for a cerebral blood flow scan. When she inhales Xenon gas, the neurological detectives will be able to observe her brain's activity, and may discover how she is making such brilliant use of her distorted brain tissue.

PICTURES OF SHARON'S ABNORMAL BRAIN

The picture appears. It shows that activity in Sharon's brain is actually focused at the back, on the bottom of the screen, in the region normally reserved for vision.

PICTURES OF NORMAL BRAIN

The normal brain, on the other hand, tends to distribute tasks evenly throughout.

SHARON'S LIVING ROOM
DOING HOMEWORK
CU SHARON
INT. KITCHEN
DECORATING A CAKE

Neuroscientists use the word "plastic" to describe how function in Sharon's brain has been redistributed from one area to another.

NICOLE OSWALD WALKING IN

George Page (V\O):
While not as complete an example of plasticity as seen in Sharon, Nicole presents another remarkable case illustrating redistribution of function in the brain following early hydrocephalus.

DR. ERIN BIGLER
Brigham Young University

Dr. Bigler (O\C):
Nicole is a young lady

	that I have been following for a number of years, ever since she was a child. In infancy, she developed hydrocephalus and required shunting. As a consequence of the hydrocephalus, extensive areas of the brain were damaged, including most of the left hemisphere.
CT SCANS OF NICOLE'S BRAIN	<u>George Page (V\O):</u> CT scans of Nicole's brain show the extensive damage that has been caused by her hydrocephalus. In this view, the left side of her brain is shown on the right side of the screen. The scan shows general expansion of the ventricles which is more prominent on the left side of the brain. The large dark area in the left rear of the brain is a cystic formation that has resulted from the hydrocephalus. This is filled with cerebrospinal fluid. There is no brain tissue there at all.
DR. ERIN BIGLER	<u>Dr. Bigler (V/O):</u> Traditionally, the left hemisphere is dedicated to language function. In Nicole's case, it has been extensively damaged including the occipital area, the area that we see with. In her case, this has affected her ability to do visual perceptual tasks. She has difficulty seeing things and identifying objects. She has difficulty carrying out any type of visual motor task: movements with

her hands, copying, using a pencil. But a very interesting and surprising thing happened early in Nicole's case, and that was that she developed normal language skills.

NICOLE AND DR. BIGLER
MOTOR EXAMINATION

George Page (V/O):
Nicole shows clear difficulties in her motor abilities as shown in this evaluation by Dr. Bigler.

Dr. Bigler:
Great. Now do it with your other hand. The same thing. Okay then bring both of your hands together. Okay. Now try to do it where you move this finger to your thumb and this finger to your thumb, and not move any of your other fingers, and do it with both hands together simultaneously.

NICOLE AND DR. BIGLER

VISUAL MOTOR EXAMINATION

George Page (V/O):
She is also unable to copy visual patterns that are directly in front of her, but as indicated, reading ability has developed normally.

NICOLE AND DR. BIGLER

READING EXAMINATION

Dr. Bigler (O/C):
I'd like you to read this for me.

Nicole (O/C):
(Nicole reads sample.)

Dr. Bigler (V/O):
Very good.

NICOLE COMPLETING ADDITIONAL TESTS

George Page (V/O):
Nicole's case, like that of Sharon, raises more questions than it answers, but they both illustrate the unusual degree of plasticity that can be shown by the brain so that uninjured areas can take over functions normally regulated by the damaged areas. Nicole's case also shows the premium placed by the brain on the ability to communicate through verbal language. Just how the brain accomplishes these feats is yet unclear, and remains a challenge for future neuroscientists.

Brain II - 2nd Edition

VISUAL INFORMATION PROCESSING: ELEMENTARY CONCEPTS: Module 8

DIAGRAM OF EYEBALL	George Page (V\O): Vision is one of our most important senses. In order to understand how this sense works, let us go to the beginning of the visual pathway, the eyes.
DIAGRAM SIDE OF EYEBALL BBC HUMAN BRAIN FOOTAGE From: Seeing	
	George Page (V/O): The eyes don't really "see." They are mere sensors, beaming information to be deciphered and reassembled by at least three million brain cells.
Wildlife Footage LION ANTELOPE CHAMELEON BIRD	
C\U HUMAN EYEBALL	George Page (V\O): In most vertebrates, each waking second, the eyes send a billion items of information to the brain.
GRAPHICS C\U EYE NEURONS	But what do all these neurons do, and how do they allow us to see? First of all, our eyes lenses' turn everything upside-down. Then the visual information is beamed along the
HEAVY FIBERS	heavy fibers of the optic nerve.
OPTIC CHIASM	The first bend in the pathway is the optic chiasm, where some of the information from the left and right eyes criss-cross. Then the pathways reach a major staging stop, at the back of the head, a

VENEER TISSUE

VISUAL CORTEX

thin veneer of brain tissue at the back of the skull. Here, at the primary visual cortex-also called the striate cortex- visual information begins its processing.

INT. UNIV. OF CA, BERKELEY

LABORATORY

Berkeley, CA

SCIENTISTS

George Page (V\O): At the University of California, at Berkeley, a team of scientists led by Russell DeValois and Roger Tatell, set out to find just what information this primary visual cortex receives.

COMPUTER
FLASHING IMAGES

This image was flashed before the eyes of a monkey. How would the nerve cells at the back of the brain encode the picture? Are visual images exposed onto the back of the brain the way images are exposed in a darkroom onto photographic paper? Dr. Russell DeValois and colleagues came up with a surprising answer.

C\U DR. RUSSELL DeVALOIS
VIDIFONT 2

Dr. Russell DeValois
University of California
Berkeley
X-RAY OF CORTEX

Dr. DeValois (O\C): The technique used was to give the monkey minute amounts of radioactive sugar, which is taken up by the most active cells in the cortex. Then when we looked at the x-ray picture of the cortex, we could see which cells were the most responsive to this pattern.

Dr. DeValois (O\C):
And the amazing thing was the precision of this pattern that we saw on the cortex, where you can see all of the stripes and rings laid out beautifully on the cortical surface. We were really amazed at ...how precisely mapping was onto the cortex.

IMAGE

George Page (V/O):
Photographs on the brain? Not quite. Without doubt, Russell DeValois and his colleagues have shown that there is precision in the way individual nerve

X-RAY

cells fire in response to what the eyes see. But this autoradiograph doesn't yet explain how those nerve cells actually decoded the image.

NOBEL PRIZE FOOTAGE
Swedish TV

George Page (V\O):
To solve the mystery, Dr. David

DR. DAVID HUBEL

Hubel of Harvard has invested three decades of research in pursuit of the answer. He and his colleague, Dr.

WIESEL RECEIVING PRIZE

Torsten Wiesel, made discoveries which won them the Nobel Prize. The brain surprised them: the way in which nerve cells of the primary visual cortex responded to an image flew in the face of their own intuition.

Dr. Hubel (V\O):
To start with, the cortex is a

INT-DR. HUBEL'S OFFICE
Harvard Medical School
Boston, MA
DR. HUBEL
VIDIFONT 3

Dr. Hubel (O\C):
a plate of cells a couple of millimeters thick, and a foot or so in surface area. The part of the cortex we're dealing with, the primary visual cortex, is a chunk of

HUBEL/SLIDE SHOW

that, about the size of maybe a credit card. And here is the real thing. This is an actual brain of a

MONKEY PRIMARY VISUAL CORTEX

Macaque monkey.

Dr. Hubel (V\O):
This is the primary visual cortex, spread out smoothly and with a tucked-under part that we can't see.

VISUALS ON PROJECTION SCREEN

Dr. Hubel (O\C):
Here, we've made a cut in the cortex, and to see what the actual cortex looks like under a

microscope, we can walk into this region and look to the left, and you see, on the next picture, what it looks like. Here is the smooth surface of the primary visual cortex; this is the part that's tucked underneath, and now, you begin to see that it's a layered structure. Some places, the cells are packed tightly; other places, they're looser. And underneath every square millimeter of cortex, which is about that much, you have something like a hundred thousand cells.

BBC FOOTAGE
"The Mind's Eye"
C\U CAT
VISUAL IMAGES

George Page (V\O):
The researchers actually listened in to individual nerve cells firing in the anesthetized cat, as they presented it with different visual images.

C\U DR. TORSTEN WIESEL
M\S DR. DAVID HUBEL
M\S CAT

Dr. Hubel (V\O):
When we started working, Torsten and I, in the late Fifties, we set up our first experiments and they didn't go well, because at the beginning, we couldn't make the cells fire at all. We'd shine lights all over the screen and nothing seemed to work.

DR. DAVID HUBEL\
DR. TORSTEN WIESEL

And, rather by accident, one day, we were shining small spots, either white spots or black spots, onto the screen, and we found that the black dot seemed to be working in a way that...at first, we

BLACK DOT AND LINE ON SCREEN

couldn't understand, until we found that it was the process of slipping the piece of glass into the projector, which swept the line, a very faint, precise, narrow line across the retina, and every time we did that, we'd get a response. Even more than that, the line produced responses that swept across the screen in one direction, but not in the reverse direction.

INT. DR. DAVID HUBEL'S OFFICE

Dr. Hubel (O\C):
Of course, that... could have simply been...an odd-ball cell. We didn't know whether we'd ever find another such cell, but after some weeks or months,

Dr. Hubel (V\O):
it became pretty clear that most of the cells that we

LINE ON SCREEN
C\U DR. HUBEL AND MONITOR

encountered in the visual cortex demanded just that kind of stimulus. Although, from one cell to the next, the orientation varied, and a number of other things differed. The line was the important thing.

LINE IMAGE

EXT. MISSION VIEJO POOL

George Page (V\O):
Russell DeValois' findings do not contradict the findings of Hubel and Wiesel. Rather they imply that some nerve cells in addition, are sensitive to the spatial frequencies of light, as in the subtle effects of sunshine on water, shadows spangling upon other shadows, a prismatic swirl of texture where edges do not seem to be the key factors.

SUNSHINE RIPPLES ON WATER

C\U DR. DeVALOIS

Dr. DeValois (O\C):
It...it's very non-intuitive, but if you take a grating pattern and add it to another pattern, it still looks like just sort of a vague, random pattern. But as you continue to add patterns of different periodicity, different variations across space, different orientations, pretty soon, it builds up into a more and more complex pattern; in fact, one that you can recognize as an identifiable human face.

B\W PHOTO OF LINCOLN

George Page (V\O):
In the nineteenth century, Impressionist painters sensed that such spatial frequencies might help create and enrich imagery.

SEURAT IMPRESSIONIST PAINTING
Art Institute of Chicago

George Page (O\C):
Whole canvases emerged out of formless points. These seemingly random dots show how spatial frequencies can operate, how clear images are sustained out of a vibration of color and light

But David Hubel is not convinced by this theory of vision.

INT. DR. HUBEL'S OFFICE
Harvard Medical School

Dr. Hubel (O\C):
It might seem a real surprise that the cells of the striate cortex have this preference for lines, because after all it's obvious that we don't see lines all the time, we see... we see...objects. But

STOCK FOOTAGE
Survival Anglia

RIVER

Dr. Hubel (V\O):
if you think of it for a minute, you realize that objects themselves consist of light-dark contours, and what the visual cortex is doing is asking, at any point in the visual world, is there a contour, and if so, what's the direction of that

contour? So, it really isn't lines that are being detected, it's contours and their directions, and that is probably sufficient information to tell you all you need to know when you look at a scene.

George Page (V\O): While the primary visual cortex, this brain area the size of a credit card, has been studied extensively, laws about the way it decodes vision are still not easy to lay down. While we may surmise that orientation, edge and frequency detection are indeed roles performed by some of these cells, there are many other cells whose function is still unknown.

Brain II - 2nd Edition

VISUAL INFORMATION PROCESSING: PERCEPTION: MODULE 9

STOCK FOOTAGE
Survival Anglia

George Page (V/O):
Seeing is only part of perception. Deciphering, decoding the image of a well-camouflaged moth, for instance, requires pathways beyond the striate, or primary visual cortex.

BBC HUMAN BRAIN FOOTAGE
From: Seeing

DALMATIAN ON B/W SPOTTED BACKGROUND

George Page (V/O):
So, too, these random spots: Bars, edges, and visual frequencies give us a sense of size and shape, but they tell us little about Dalmatians. Higher visual area in your brain are now at work, a region of near-unexplored brain territory to which Dr. Mortimer Mishkin has devoted much of his research.

INT. DR. MORTIMER MISHKIN'S OFFICE
National Institute of Mental Health
Bethesda, MD

M/S DR. MISHKIN AND BRAIN MODEL
VIDIFONT 6
Dr. Mortimer Mishkin
National Institute of Mental Health

Dr. Mishkin (O/C):
The striate cortex is simply the first station... in the cerebral hemispheres to receive information from the retina, and it looks as though the striate cortex in the back part of the brain sends information forward along two different pathways; one headed to the top part of the brain, to what...to a region that we call the parietal lobe, and another headed toward the bottom part of the brain, toward a region that we call the ventral part of the temporal lobe.

ALLISON ANIMATION
Whole Brain Model

George Page (V/O):
The higher pathway, plunging in and out of the exterior cortex, makes a series of very specific visual computations.

SEURAT IMPRESSIONIST PAINTING
Art Institute of Chicago

ALLISON ANIMATION

SEURAT IMPRESSIONIST PAINTING

DOG
CHILD
MAN

ALLISON ANIMATION
Neural Net

GRANDMOTHER PHOTOGRAPHS
1.Grandmother w/scarf (Don Perdue)
2.Sara Cares COLOR (Don Perdue)
3.Grandmother at table COLOR (Don Perdue)
4.Grandmother at window COLOR
5.Susan Kim's Grandmother B/W
6.Peter Bull's Grandmother B/W
7.Rose Harrison/Bubbie Dancing B/W
8.Grandmother w/scarf and glasses B/W (Chester Higgins)
9.Rachel Bensussan (Jackie Donnet)

George Page (V/O):
Its role is to tell us where things are in the visual field, to specify that the dog is in front of the mother and child, to establish that this couple faces the far away lake. Clearly, this pathway helps us orient one object to another, a visual back and forth that continues as long as our eyes remain open. The lower pathway's function is possibly the most surprising of all. In a similar series of stages, it helps us explain what objects are. It tells us that this is a dog; this is a child; this is a man. As neuroscientists investigate our visual system, they find that our brain cells here are very, very specific. In the 1950's, some neuroscientists called them "grandmother" cells. The theory, which enjoyed a certain popularity, was that we might actually possess a single cell that lit up when our grandmothers came into view, and another cell for each and every person we ever saw. These cells were pictured as being almost miniatures of that person. However startling the theory, it now seems that these

cells at the end of the lower pathway actually might be similar to grandmother cells.

INT. DR. MISHKIN'S OFFICE
VIDIFONT 7

<u>Dr. Mishkin (O/C):</u>
Some of my colleagues working in Princeton and Oxford University have recently shown that they can record from single neurons in part

C/U BRAIN MODEL

of the inferior temporal lobe, and these neurons will be activated by faces...better than by any

B/W ANIMAL SKETCHES
1.Baboon front view
2.MONKEY side view
3.MONKEY front view distorted
4.MONKEY WITH WHITE BAND

<u>Dr. Mishkin (V/O):</u>
other kind of stimulus that they can present. Not only will they be activated by faces, but if the faces are distorted in certain ways, the neurons will not respond.

5.MONKEY front view
6.MONKEY side view
7.SPLIT MONKEY
8.MONKEY

<u>George Page (V/O):</u>
As we watch, we can hear single cells in the inferior temporal lobe of monkeys reacting to a single monkey face. The cell only fires if the face is at the right angle and is not distorted. What distinguishes these very specific cells from the so-called "grandmother" cells of the 1950's is that they rely on many other cells in the visual pathway to feed them detailed information. They are called cumulative cells.

B/W PHOTOGRAPH FOREHEAD

George Page (V\O):
And so, grandmother is not merely embodied in a single cell. She is represented in our brains by a multitude of cells, some so simple

B/W PHOTOGRAPH-Sara Cares (Don Perdue)
COLOR PHOTOGRAPH Sara Cares (Don Perdue)

that they merely analyze the bars and edges of her face, the visual frequencies of her complexion. And some so complex that, in the lower pathway of vision, a single cell might actually light up when we see our own grandmothers, but only with help from the hundreds of thousands of cells that precede it...

COLOR PHOTO GRANDMOTHER-Sara Cares (Don Perdue)

Dr. Leslie Ungerleider's Lab
National Institute of Mental Health
Bethesda, MD

George Page (V\O):
Utilizing modern brain research techniques, Dr. Leslie Ungerleider, a colleague of Dr. Mishkin at the National Institute of Mental Health, has been studying the process of human facial recognition.

Dr. Leslie Ungerleider
National Institute of Mental Health

Dr. Ungerleider (O/C):
Until recently, our understanding of how the brain codes visual information has come mainly from studying the activity of single neurons in the monkey brain and also by looking at impairments in patients following brain damage. But now

SUBJECT BEING SCANNED ON MRI

with advances in the new technology of functional magnetic resonance imaging, we can look directly at activity in normal, healthy individual's brains and

	we can see how that activity changes as these human subjects are involved in various kinds of tasks. We are
FACIAL STIMULI	especially interested in what happens in the brain when people perceive, recognize and recollect faces.
DR. UNGERLEIDER	Dr. Ungerleider (O\C): Just as we have found in our monkey work, our imaging studies in humans indicate that there are specialized regions in the temporal lobe of the human brain that appear to be specialized for the processing of faces. When we see faces, these areas of the cortex become active.
FUNCTIONAL MRI VISUAL-OCCIPITAL	Dr. Ungerleider (V\O): Imaging studies have also shown that beyond
FUNCTIONAL MRI VISUAL-FRONTAL	the visual cortex, there are areas in the frontal lobe that are involved in the processing of faces. In particular, these areas become active
FACIAL STIMULI	when we see a face, and then must hold that face in mind when it's no longer present in order to recognize it a short time later.
FUNCTIONAL MRI VISUAL-FRONTAL	Studies such as this tell us that areas of the frontal lobe are involved in maintaining these short-term memories for faces.

DR. UNGERLEIDER

<u>Dr. Ungerleider</u> <u>(O\C):</u>
We also have evidence that the very same areas of cortex that are involved in the processing of information about faces also participate in the long-term storage of memories for faces for subsequent recollection.

PHOTO OF GRANDMOTHER

In fact, when we imagine a face in our mind's eye, these very same areas of cortex become active.

STOCK FOOTAGE-Survival Anglia
ANIMAL HERD

<u>George</u> <u>Page</u> <u>(V\O):</u>
Higher vision is not limited to faces. It may help pick out the one lame animal in a herd of twenty-five thousand.

LION

For the lion, such visual computations are

LION RUNNING FOR ZEBRA

everyday tasks. Does he, could he, meticulously, examine all hundred thousand legs for wounds? Or does he look for visual exceptions...for an irregularity of movement that stands out more clearly than a bloodied leg? How do we spot an old friend walking away from us in a crowd? By the color of his socks? Or by the way he moves? Either way, while we call this process "seeing" it's a very high order of

ALLISON ANIMATION
Brain Model

seeing: It's perception. and how long does it all take to happen? Well, the process of seeing and perceiving something as elementary as a flash of light takes

JESSE SALB'S EEG TOPOGRAPHIC

about three tenths of

MAP SEQUENCE-Vision

a second. There. That's it. That's vision. Blink your eyes and you might have missed it. Slowed down, the route of vision is clearer. First, we can see the back of the brain light up here in the area studied by Hubel, Wiesel, and DeValois. Now, with images being computed along those pathways of Mortimer Mishkin, the collective information reaches the front of the brain: the thinking part of the brain, and it's now when we realize what we've just seen.

PERCEPTION: INVERTED VISION: MODULE 10

BBC HUMAN BRAIN FOOTAGE
From: Seeing

George Page (V\O): For another clue to the brain's remarkable adaptability, consider Susannah Fiennes, a London art student who has agreed to undertake a curious experiment.

C\U SUSANNAH FIENNES DRAWING

In order to appreciate this experiment, we need to review how the visual mechanism operates in our normal everyday encounters.

ANIMATION OF VISUAL MECHANISM

For example, when an object appears in our visual world, the image passes through the lens of the eye and in that process, it is inverted onto the retina. The image is then passed along the visual pathway to the visual cortex at the back of the brain, where it is perceived as being right-side up.

INT. MR. HOPKINSON'S OFFICE
London, England
MR. HOPKINSON AND SUSANNAH FIENNES

George Page (V\O):
By placing these unusual spectacles on Susannah, we can invert her visual world and for one whole week she will see everything upside-down, inverting once again what the lens of the eye does anyway.

SUSANNAH FIENNES

Susannah Fiennes (O\C):
I can't quite see your face. Is that possible?

HOPKINSON UPSIDE-DOWN

George Page (V\O):
Our brains normally correct for this inversion. Now hers will be forced to make yet another correction. Will she be able to make sense of an upside-down world?

UPSIDE-DOWN BUS
UPSIDE-DOWN DESK

Susannah Fiennes (V\O):
It' really peculiar...Wrong way. It's going the wrong way. I can't...the car is going upside-down. Oh that's really weird.

C\U SUSANNAH FIENNES

Susannah Fiennes (O\C):
Oh no. Oh! Where is it? 'Cause I'm sure I'm holding the cup...Oh.

George Page (V\O):
At home, an hour later, the world is still bewildering.

UPSIDE-DOWN PITCHER AND CUP

Susannah Fiennes (O\C):
Got it. It's funny. I can just suddenly do it. Lost it again. Oh, dear. What to do now? It's extraordinary.

RIGHT-SIDE UP
UPSIDE-DOWN
CU SPECTACLES
C\U SUSANNAH WRITING

George Page (V\O):
On the third day, Susannah tries to write her name without looking.

BBC HUMAN BRAIN FOOTAGE
INT. SUSANNAH FIENNES' FLAT

Susannah Fiennes (V\O):
Oh...now it's rather difficult to know which end to start...What's happening... oh, no. It's getting worse and worse. I can read ha...I can read that end, but not the rest of it. Shall I try and write it...now, so I can read it all?

SUSANNAH FIENNES WRITING

George Page (V\O):
Once she looks, she's able to invert the letters completely. Clearly, in three days, she's made progress integrating upside-down seeing with upside-down moving.

Susannah Fiennes (V\O):
There. Now I can read that quite easy.

M/S SUSANNAH FIENNES DRAWING

George Page (V\O):
On Susannah's final day, she tries to draw.

C\U SUSANNAH FIENNES

C\U SIGNATURE ON PAINTING
EXT. ENGLISH COUNTRYSIDE

With a week's practice, she can now sign her name to the drawing right-side up, while looking. The seeing part of Susannah's very flexible brain has somehow matched the unchanged world to her altered vision.

L/S SUSANNAH FIENNES RIDING BIKE
UPSIDE-DOWN
RIGHT-SIDE UP

INT. SUSANNAH'S FLAT

<u>Susannah</u> <u>Fiennes</u> <u>(O\C):</u>
Right. Well, I've been wearing them for a week...and I'm going to take them off and try and walk across the room. I don't think I dare do it. It's very terrifying. Ah! It's really extraordinary.

EXT. ENGLISH COUNTRYSIDE

Ooh! That was funny. That is just so incredible...just to feel everything... the world around me again. Amazing.

LAKE AND WATER TOWER

<u>George</u> <u>Page</u> <u>(V\O):</u>
And now Susannah Fiennes' brain has managed yet another inversion of the image...

<u>Susannah</u> <u>Fiennes</u> <u>(V\O):</u>
What an...extraordinary feeling.

<u>George</u> <u>Page</u> <u>(V\O):</u>
And this time, it's taken just one hour.

BBC HUMAN BRAIN FOOTAGE

SUSANNAH FIENNES

EXT. MEADOWS
England

Susannah Fiennes (V\O):
And then, suddenly, I just feel as though nothing has happened. If you look around...everything seems completely normal again.

George Page (V\O):
This basic pathway of vision is, therefore, flexible, plastic. It is ready to help us adapt to a world that changes.

5