the ESP., São Paulo, n. 18, 01-22, dez. 1987

THE DUAL REPRESENTATION OF INFORMATION IN MEMORY AND IN WRITTEN DISCOURSE AND SOME IMPLICATIONS FOR FOREIGN-LANGUAGE READING

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RESUMO

Este artigo relaciona aspectos teóricos referentes à organização e representação do conhecimento humano na memória de longo termo à estrutura do discurso escrito para, então, estabelecer algumas implicações pertinentes ao ensino de leitura em língua estrangeira. Parte do pressuposto de que existe uma analogia entre a maneira pela qual a informação se encontra organizada e representada na mente humana em termos de dois sistemas cognitivos: o verbal e o de imagem e a maneira pela qual a informação se encontra estruturada no discurso escrito em termos de seus dois componentes semióticos: o verbal e o não-verbal. Estabelece, então, a seguinte implicação para o ensino de leitura: a tarefa de interpretar um texto em língua estrangeira pode ser facilitada se o aluno-leitor fizer uso dos elementos não-verbais — aqueles que se encontram representados em seu sistema cognitivo de imagem — para iniciar o processamento da parte verbal do texto a ser interpretado; o resultado pode ser uma compreensão mais eficiente e, por conseguinte, uma maior retenção de informação para usos futuros.

1. PRELIMINARY REMARKS

This paper relates Paivio's dual-coding theory (1981), which claims that world knowledge is stored in human memory in terms of verbal and visual representations, to the structure of written discourse with its two basic semiotic devices: verbal and nonverbal. The main purpose is to argue that Foreign-language reading(hereafter FL reading) will be more efficiently handled if the nonverbal elements of discourse are used to initiate the processing of new incoming information.*

The rationale underlying my argument is as follows: first, there seems to be an analogy between the way information is represented and organized in human memory in terms of verbal and image systems and the way the information is conveyed in written discourse in terms of verbal and nonverbal elements, as both rely on verbal and image systems. Second, the dual-coding theory claims that either one of our cognitive systems – image or verbal – can initiate activity in the other. Third, a reader, when actively involved in his construction of meaning, may initiate his processing of information by making use of one of the components of written discourse – either verbal or nonverbal discourse. Therefore, what I argue is that the task of the FL reader-learner may be greatly facilitated if he uses nonverbal elements – the ones dealt with by his image system – to initiate the verbal processing of new information.

It might be appropriate to mention that comprehension of a text is currently viewed as an interactive process involving both text-presented material and the reader's knowledge of the world which is brought to the comprehension task. The comprehender plays a fairly active role in his construction of meaning by inferring, predicting, guessing, establishing the continuity of a written text, and so on. It may be said that meaning emerges from the dynamic interaction of new incoming information, that is, the verbal and nonverbal guides provided by the written text itself, and the reader's previous knowledge. In other words, comprehension does not lie exclusively in the text or the reader, but in the interaction between both.

It is also my argument that the use of the nonverbal elements of discourse may decrease the cognitive overload in the reader's interactive involvement with the processing of new information. Thus, by chunking larger pieces of information through nonverbal elements, the FL reader-learner may be able to overcome the limited capacity of short-term memory and free his brain to carry out the complex activity of processing information faster and more fully.

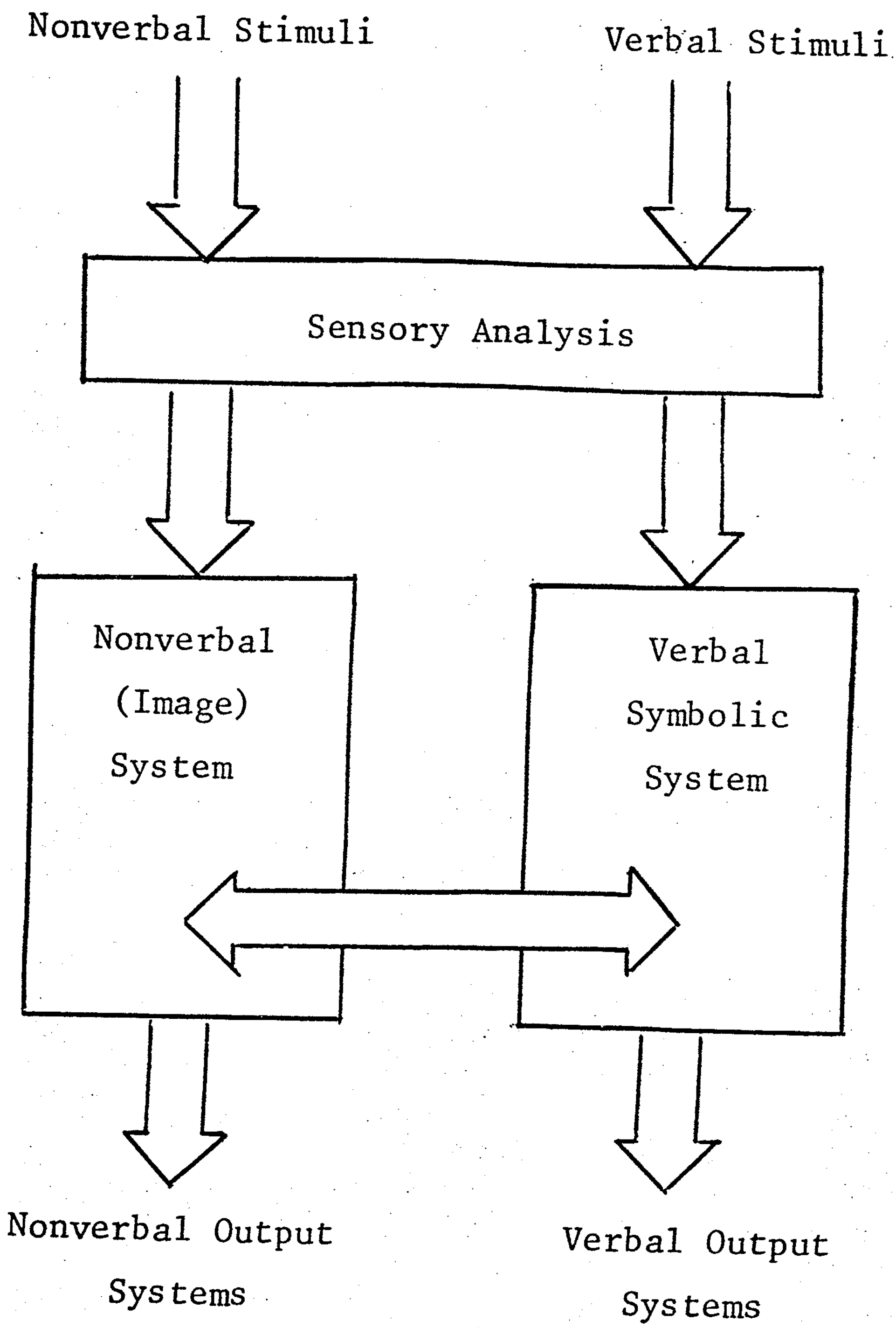
This paper will thus be first concerned with a theoretical description of the dual-coding theory; next, the structure of written discourse will be discussed and then some implications for FL reading will be considered.

2. THE DUAL-CODING THEORY

According to the dual-coding theory, information is stored in human memory in two ways: as visual images and as verbal representations. Paivio (1981: 67) describes his theory thus:

> "Its principal assumption is that language behavior is mediated by two independent but partly interconnected cognitive systems that are specialized for encoding, organizing, transforming, storing, and retrieving information. One of these (the image system) is specialized for dealing with information about nonverbal objects and events. The other (the verbal system) is specialized for dealing with linguistic information."

Appropriately, Paivio (1981: 69) provides a schematic representation of the two systems:


Nonverbal Stimuli
Verbal Stimuli
Sensory Analysis
Nonverbal (Image) System
Verbal Symbolic System
Nonverbal Output Systems
Verbal Output Systems

As indicated above, each system is independent in that activity can take place in one system or the other, or both in parallel (simultaneously). Thus, it is possible to

> ... imagine a scene without necessarily describing it verbally, talk about some things without necessarily experiencing imagery, or do both simultaneously as when we describe some familiar scene from memory. We can even imagine familiar things while talking about something quite different. Such common experiences are evidence of the independence of the systems. (Paivio 1981: 68)

As also indicated in the graph above, the two systems are interconnected because information can shift from one system to the other. Paivio (1981) explains that we can make symbolic transformations from one kind of information to the other, or more precisely, one of our symbolic systems can initiate activity in the other.

For example, suppose someone is asked to imagine the most important sights of his town and to describe their appearance, location, and so on. The dual-coding theory posits that this is possible only if there is a link between the language system that receives and interprets the request and the memory system that contains the information about the appearance of the sights. What happens is that the verbal input is transformed into nonverbal imagery which is finally decoded and expressed verbally. The following diagram summarizes the example just given — the arrows represent the input from one processing stage to another.

INPUT	MEDIATING COGNITIVE EVENTS			
"Describe the most important sights of your town" ⇨	verbal system inter- prets instruc tions →	image system generates the sights →	verbal system inter- prets image ⇨	Descrip- tions of the sights

It may be also relevant to point out that this sequence of events can be reversed in case the input is a nonverbal object or picture. According to the dual-coding theory, the perceptual information is first interpreted by the image system. This image system then generates representations in the verbal system when one makes verbal references to the nonverbal stimulus.

Paivio (1981: 70-71) also makes important qualitative distinctions between the two systems:

> "The nonverbal (image) system can be viewed as an analogue system in the specific sense that some knowledge of the world is represented as perceptual analogues of concrete objects and events. ... The verbal system, however, contains information whose units are discrete or digital in nature and only arbitrarily related to the objects and events they signify.
>
> The qualitative differences extend to the way units of information are organized into higher-order units in the two systems. The image system organizes information in a synchronous or spatial manner, so that different components of a complex thing or scene are available at once in memory.
>
> In contrast, verbal information is

> organized sequentially into higher-order structures. ... Linguistic units unfold sequentially over time, and the assumption is that the cognitive system that deals most directly with speech is similarly specialized for sequential processing."

The representation of information in human memory according to the dual-coding theory with its image and verbal systems finds a parallel in the representation of information in written discourse with its verbal and nonverbal codes, a point that will be discussed in the next part on the semiotics of written discourse.

3. THE SEMIOTICS OF WRITTEN DISCOURSE AND FL READING

In written discourse information is conveyed not only by passages of prose, but also by nonverbal devices such as pictures, graphs, maps, tables, formulas, line drawings, diagrams, and so on. This means that the communicative function of a text is not conveyed exclusively by verbal means — nonverbal elements contribute to the whole communicative meaning as well, either by supplementing verbal statements, or replacing them, or providing a general idea of what the text is about, or still as a visible form of the verbal information, as for example, in graphs. Widdowson (1983: 73-74), inter alia, argues that these devices

> "are incorporated into the discourse and relate to the actual verbal text to form a cohesive and coherent unit of communication."

He also remarks that nonverbal devices constitute fundamental features of the basic rhetoric of written discourse.

Indeed, the content of science textbooks is represented by written discourse which contains both verbal and nonverbal components. These materials present a great deal of nonverbal information together with the linguistic information itself. This non-textual information is in fact fully integrated with the linguistic part of the text — the verbal text explicitly refers to this nonverbal information and, consequently, cannot be totally understood without it. Part of the learning of science is the understanding of how nonverbal elements work and how they are related to the verbal text itself. This means that students of different areas have to interpret the essential features of written discourse — with its two basic components — in their learning of the subjects of their school curriculum.

Scientific discourse — the discourse which is written by a specialist to address other specialists and to convey some relevant new information to their field of study — normally makes use, according to Vigner (1979) of three semiotic devices:

- the verbal text — its linguistic component proper
- the graphic language of diagrams, graphs, illustrations
- the formal language — made up of formulas and conventional symbols.

It is important to point out that these three semiotic codes are in a relation of meaning complementation — one of the codes adds to what has been provided by the others and vice-versa. The main purpose in using them is directly relevant to accuracy. Another point is that the writer knows in advance the conditions of reception of his message, since he writes for a homogeneous group. The result is a concise and straightforward text.

Articles and essays of the so-called "scientific vulgarization" — e.g. "Science Digest", "Scientific American", "Science", specialized parts of "Time", and so forth — also present information through the use of different semiotic devices mainly as a means to increase its degree of readability. (Vigner 1979: 56) In them the information is not usually conveyed by the linguistic code only but also by other devices such as accompanying illustrations or diagrams, captions under the illustrations, the labels of the diagrams, use of different typefaces, appealing titles or sub-titles which most commonly sum up and stress the main information to be presented, and so forth.

As these articles and essays are written with the purpose of reaching a large readership, including lay readers, they must contain a multiplicity of different semiotic devices which facilitates comprehension, that is, which decreases the readers' effort in their construction of meaning. The same information is often conveyed by various of these means to guarantee understanding. Since the writer cannot establish in advance the shared area of background knowledge between himself and his readers, he uses different devices which make the readers' processing of new incoming information easier.

Still as a consequence of this imprecise shared area, the writers of scientific vulgarization usually assume that readers lack the necessary background knowledge in the specific area they are writing about. Therefore, these articles and essays have the additional function of instructing the readers, or rather, make the reader acquainted with basic points that are necessary to the comprehension of the information they convey.

As pointed out earlier, comprehension of a text is only partially determined by the text itself, it is rather an interactive process which involves an interplay of text-presented material and the reader's knowledge of the world. This means that the reader not only makes use of the two basic semiotic devices of written discourse, but also brings previous knowledge to his processing of information. Widdowson (1983: 73) in fact argues that the

> "interpreting of written discourse involves the processing of these non-verbal elements and a recognition of their relationships to the verbal text." (emphasis added)

Since the articles and essays of scientific vulgarization are particularly interesting in displaying a close relationship between verbal and nonverbal elements, it might be appropriate to analyze an article in terms of the devices used to increase its degree of readability.

In this article, entitled "Acid Rain" (in Science Digest, September, 1984: 39-49), the author conveys his intended meanings through a highly contextualized passage — there is a close, and indeed important, relationship between verbal and nonverbal elements in an attempt, as just mentioned, to increase the degree of readability of the article. Since the author writes for a large number of readers, and it is difficult for him to predict his readers' preexisting knowledge about this kind of acid precipitation, he conveys his information in a redundant way, that is, through different semiotic codes: if the reader fails to understand one of the codes, he is able to apprehend the information by making use of the other codes provided. This means that, used together, verbal and nonverbal information reinforce each other: an obscure part of a text may become clear by an analysis of an illustration, or the importance of an illustration may be readily perceived by reference to the verbal information presented in the surrounding text.

The author also guides his readers into formulating hypotheses while they are involved in the construction of the meaning of the article. For example, the title is not shown clearly on the first page. However, two important clues are given: one at the top of the page, the other at the bottom. (See appendix) The information at the top is conveyed linguistically by the use of the sentence: Our trees are dying; this information is also stressed in a nonverbal way by the illustration showing trees in poor condition; it is conveyed a third time, linguistically, by the caption just below the illustration which says: Denuded trees atop Vermont mountains bode a bleak future. Furthermore, there is also a visible contrast between the typeface used in Our trees are dying and the one used in the caption. The reader can thus go from the linguistic information to the illustration, and then to the caption. The words trees, dying, and denuded probably become clear by the illustration; the meaning of the word bleak and the meaning of the verb bode are probably inferred by reference to the context of situation. The reader has then at his disposal different clues to confirm his expectations and comprehend what he is reading.

On the other hand, the information given at the bottom of the page is almost totally linguistic, except for the fact that it is in bold-face type and in upper-case. It can, however, be related to the illustration presented at the top. The reader can then infer a causal relationship between the two items of linguistic information: Acid Rain is not an ecological curiosity but a growing global concern that threatens to ravage our forests (bottom) and bleak future (top), that is, the destruction of forests will result in a bleak future. At this stage, having relied on verbal and nonverbal clues to instantiate his schema, the reader makes his hypotheses as to what the undesirable cause may be. When he turns the page, he may confirm his hypotheses by the title of the article, "Acid Rain".

If the reader glances through the article paying close attention only to the illustrations on page 41, for example, begins with a large B and deals primarily with the sources — anthropogenic and natural — of the amount of sulfur in the atmosphere. (See appendix) The sub-block on page 44 begins with a large A and deals primarily with the effects of acid deposition in different locations. The sub-block on page 45 begins with a large D and deals primarily with the effects of acid rain on some types of trees.

As pointed out earlier, the illustrations provided serve as a guiding force in the reader's understanding of the overall gist of the article. On the linguistic level, the first part of the article (page 39 - see appendix) serves this function: if the reader grasps only its gist, he is capable of forming the overall view of the development of the information through the article. It may be appropriate to call attention to the fact that two nonlinguistic devices are used within this part of the text: it is written in bold-face type and the term "acid rain" is written in italics to draw the reader's attention to the point where it is defined. Again the text iconography itself provides clues to meaning.

Within each sub-block of information important nonlinguistic devices such as numbers, formulas, parentheses, quotation marks, proper names in capital letters, and abbreviations are recurrently used. They serve as hints in the reader's "negotiation of meaning". (Widdowson 1984: 64)

It seems possible to remark that this alternative use of verbal and nonverbal information is a powerful device in guiding the reader's interpretation of written discourse. He has at his disposal different clues which may be used to retrieve his knowledge of the world from his memory, thereby comprehending more effectively what he is reading.

It may be appropriate to reiterate that the interpretation of written discourse cannot be equated with the decoding of the linguistic information only; interpreting is rather the simultaneous processing of different codes which are sometimes redundant, sometimes complementary, sometimes both. It can be said that the use of a network of different semiotic devices really facilitates comprehension since the reader can go from one code to the other, go back to the first, and so on.

A point must be made about the use of graphs, that is, systems of visualization of the main bits of information provided by the text they go with. According to Vigner (1979), a text with an accompanying graph conveys the same information four times:

- by the graph itself, that is, the whole
- by the visualization of the elements such as figures, numbers, drawings dealt with graphically
- by the caption of the graph
- by the linguistic text itself

Again the phenomenon of redundancy is evident — this multiplicity of codes contributes to a secure conveyance of the same information — the reader has then different options at his disposal in his processing of the same information: he may begin by an evaluation of the graph and its elements, then go to the linguistic text, go back to the graph, then to the caption, and so on. Furthermore, graphs have a powerful symbolic value — they not only have an extraordinary aesthetic value (some graphs are self-explanatory), but also suggest scientific exactness and accuracy. Thus, the information conveyed graphically has the advantage of being interpreted as precise (whether it is or not!)

Vigner (1979) also points out that graphs in specialized scientific works and magazines bear a meaning complementation rather than a redundancy relationship. They are normally carefully scrutinized by the reader since they more often convey the essential bits of information of the text they go with.

It is beyond the scope of this paper to provide an in-depth discussion of the use of the various semiotic devices in scientific discourse proper and in the documents of scientific vulgarization. My main purpose is simply to call attention to the fact that semiotic devices — verbal and nonverbal — are in close relationship, sometimes in a relation of meaning complementation, sometimes in a relation of redundancy of meanings, sometimes both, a point I rely on to advocate the use of the nonverbal elements of discourse by the FL reader-learner, which may facilitate his negotiation of meaning.

4. FINAL REMARKS

This paper has tackled the following issues within the point of view of cognitive psychology: how our knowledge of the world is organized and represented in human memory and how information can be processed by our brain in terms of Paivio's dual-code theory. It has also discussed the interrelationship of verbal and nonverbal elements in written discourse. Some implications for FL reading have then been considered. First, the FL reader-learner may make use of the nonverbal elements of discourse, the ones dealt with by the image system, to initiate a proper construction of meaning in the foreign language. Second, better comprehension and consequent retention of what he reads will take place, as he is making full use of his memory structure and the structure of written discourse.

NOTE

*In his article "Non-linear information and the Text" (in ESPecialist no. 11 1985: 46-85), Anthony Deyes gives an account of the relationships between linear and non-linear information and discusses some ways in which non-linear information might be used to improve /facilitate reading comprehension.

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APPENDIX

SCIENCE digest

OUR TREES ARE DYING

Denuded trees atop Vermont mountains bode a bleak future.

BY NIGEL SITWELL

The term *acid rain* was first coined in 1872 by Robert Angus Smith, an English chemist who used it to describe the increasingly acid precipitation that fell on the industrial city of Manchester. In fact, it is now generally agreed that acid rain is a product of the Industrial Revolution, for it stems largely from the burning of coal and oil.

In the intervening century, acid rain has been transformed from an environmental curiosity to perhaps the most pernicious global problem of the age. The specter of mass deforestation is real. But the forests of the industrial world are not the only victims. Entire lake regions are becoming sterile and devoid of life. Monuments that have withstood the erosion of centuries are being transformed into soft gypsum and may soon be washed away. Even human health could be at stake if acidified groundwater continues to leach out trace metals into the world's drinking supply.

Acid rain is a worldwide problem. It has been reported in Brazil, China and South Africa. And now the Arctic, one of the world's last great wilderness areas, has become a victim. Surprisingly high levels of pollutants have been found, and the presence of soot, or black graphite carbon particles, which can only be created by combustion, strongly suggests an in-

ACID RAIN IS NOT AN ECOLOGICAL CURIOSITY BUT A GROWING GLOBAL CONCERN THAT THREATENS TO RAVAGE OUR FORESTS.

ACID RAIN

dustrial origin. Arctic haze now covers a huge area in winter and early spring and restricts visibility to as little as two miles. The pollution is thought to come from the Soviet Union.

When fossil fuels are burned, they release large amounts of waste products, such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Once in the atmosphere these reactive gases may combine with water and oxygen to form sulfuric and nitric acids, which fall back to Earth as acid rain. Or they may fall in their original gaseous form or as very fine particles. Scientists prefer to call the first kind wet deposition and the other two dry deposition, or they might call the whole phenomenon acid deposition rather than acid rain. And in any case, wet deposition can take the form of snow, hail, fog, mist or dew. The words *acid rain* are so expressive, however, and so widely used that they are unlikely to be replaced by the more accurate terms.

Acid precipitation in the eastern United States is now as much as 40 times as acidic as "normal" rain, as measured by free hydrogen ion concentrations. This is confirmed by examination of samples of preindustrial rain entombed deep inside the Greenland ice cap.

It is believed that oxidation of SO_2 is much slower than that of NO_x (the x subscript indicates all nitrogen oxides), so that SO_2 may remain airborne for three or four days, compared with NO_x, which may persist for only half a day. This has significant consequences if true, for it means that acid rain derived from SO_2 is transported hundreds or even thousands of miles, while rain produced by NO_x travels only tens to hundreds of miles. Also, each sulfur molecule contributes twice as much acid as each nitrogen molecule, so as much as three-fourths of the total acid falling on land in the eastern United States originates in sulfur emissions.

Sulfur dioxide is emitted by a variety of sources. Emissions in the United States in 1980 totaled 24.1 million metric tons. Of this, 66 percent came from electric utilities, 22 percent from industries and minor amounts from other sources. But smelting can produce large sulfur dioxide emissions when the ore contains sulfur—as it does with metals such as copper, zinc, lead and nickel. In Canada, smelting contributed 45 percent of the SO_2 emissions, compared with only 6 percent in the United States.

Soils and waters have in the past received, and still do receive, acid from a wide variety of natural sources, including volcanoes, forest fires and the decomposition of plants and animals. Oxidation of carbon dioxide to form carbonic acid is also a major natural source. Lightning combined with nitrogen oxides in the air produces nitric acid.

But it has been estimated that while on a global basis natural sources contribute about the same amount of sulfur to the atmosphere as do human (anthropogenic) activities—about 75–100 million tons each—anthropogenic sources dominate natural ones in industrial regions like North America and Europe, where the latter may be only about 5 percent of the total. For instance, the giant 1,150-foot stack of the International Nickel Company's Sudbury, Ontario, smelter releases twice as much sulfur every year as Mount St. Helens spewed out in its most active period.

It is more difficult to make a similar comparison between natural and anthropogenic sources of nitrogen oxides, but the ratio is probably much the same.

Once airborne, the sulfur and nitrogen oxides eventually come down again, in one form or another. Precisely where depends both on the stack height at the source and the weather conditions. In general, prevailing winds in North America tend to transport pollutants toward the east.

This fact is the key to understanding one of the principal political problems involved in acid rain. The nine largest coal-burning states lie in the Ohio basin–Midwest area and are estimated to contribute about two-thirds of all sulfur dioxide depositions within the eastern states. In fact, the pattern of transport is quite complicated, with the United States contributing a sizable proportion of eastern Canada's acid, while Canada in turn contributes part of the acid deposited on the eastern United States. A June report by the National Clean Air Coalition indicated that the problem had extended to 13 southern states, ranging from West Virginia to Florida. In this case, the area itself is said to be responsible for two-thirds of the pollutants.

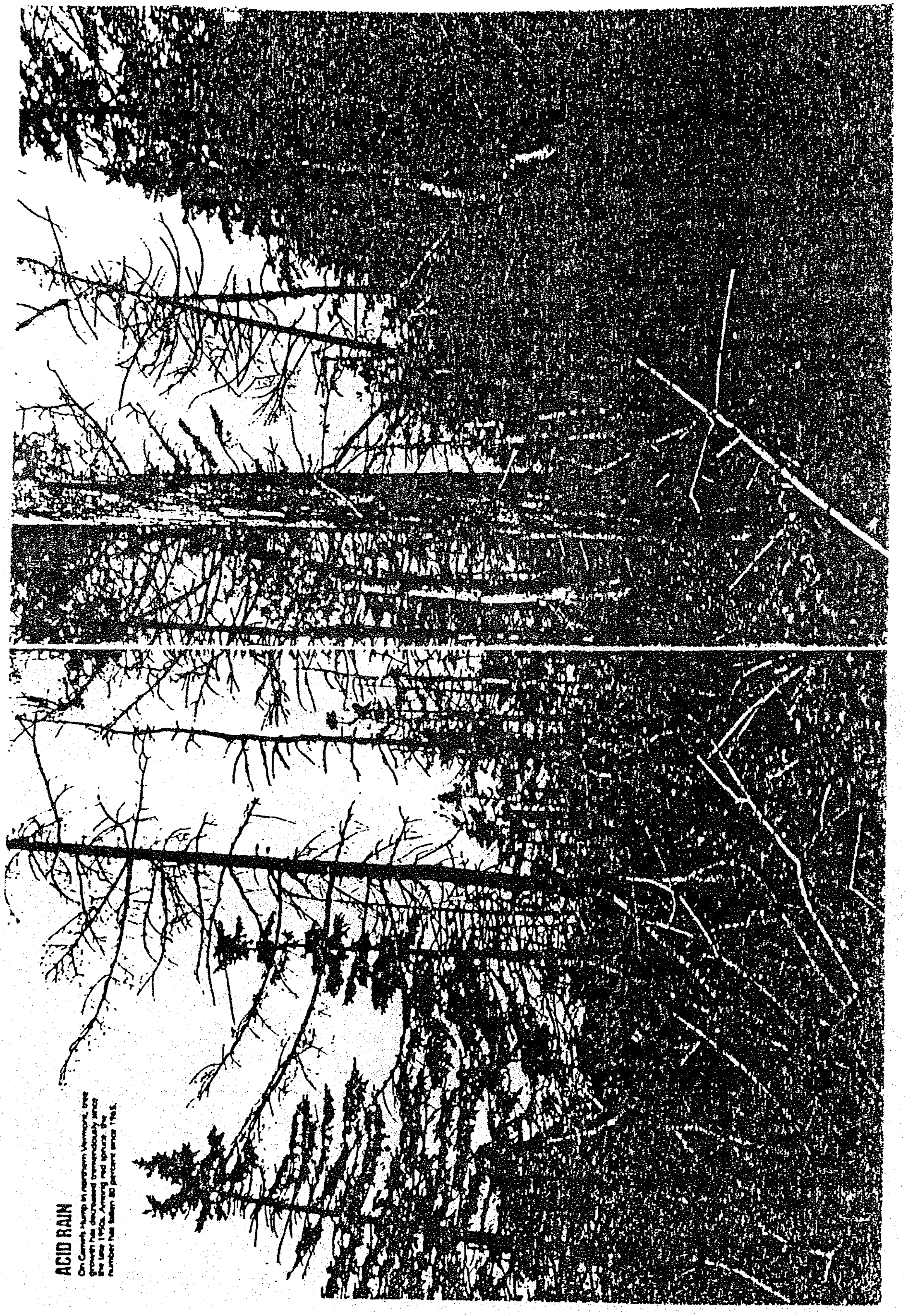
OVER 4,000 LAKES IN SWEDEN ARE NOW FISHLESS, AND IN WEST GERMANY, AT LEAST HALF OF THE FAMED BLACK FOREST IS DAMAGED.

Acidity is measured on the pH scale, which is based on the negative logarithm (to the base of 10) of hydrogen-ion concentration. The scale runs from 0 to 14, with a value of 7 being neutral. Above 7 is alkaline, and below 7 is considered acid. Because the scale is logarithmic, a decrease of one full point on the scale represents a 10-fold increase in the number of hydrogen ions. Thus pH 4.0 is 10 times more acidic than pH 5.0, and pH 3.0 is 100 times more acidic than pH 5.0.

"Normal" rainfall is slightly acidic because of dissolved carbonic acid. It has traditionally been given the value of pH 5.6. However, scientists have recently concluded that rain is naturally variable in acidity and should probably be given a mean acidity value of 5.0 with a maximum of 4.5. Measurements of pH are not very accurate and, because of environmental variations, can only provide a broad picture of the situation. Furthermore, these measurements deal with wet depositions. Particulate or gaseous depositions are eventually converted

Nigel Sitwell has written for many British journals about the problems of acid rain.

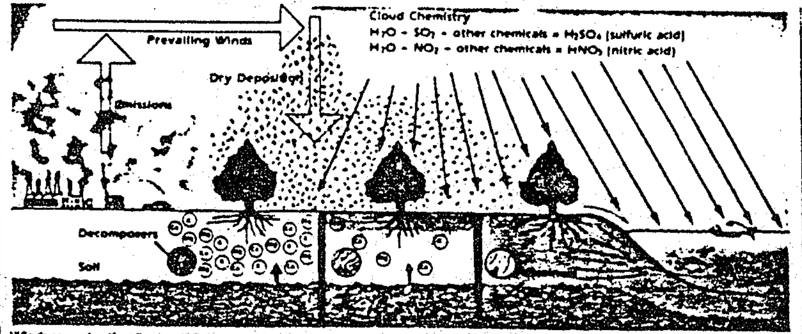
A murky chemical cloud pours from a stack. Scrubbers could minimize sulfur emissions but are costly. New York State, however, recently required three existing plants to install units if they plan to burn coal.



ACID RAIN

On Camel's Hump in northern Vermont, tree growth has decreased tremendously since the late 1950s. Among red spruce, the number has fallen 50 percent since 1965.

ACID RAIN



Winds spread sulfur dioxide (SO_2) and nitrous oxides (NO_x); sunlight and water vapor convert them to acids. (1) In the first stage of acidification, the thin soil is full of essential decomposers and nutrients—calcium (Ca), magnesium (Mg) and potassium (K). Ca is a buffer against acidification; bedrock replaces lost minerals. (2) Acid builds up in the soil when the soil's neutralizing ability is depleted. It leaches nutrients and strips leaves of their protective coating. (3) Finally, sulfate and aluminum combine to form a poison that kills decomposers, destroys the fine-root system of trees and washes into lakes to kill fish by damaging their gills.

into acid too, so they are just as important as wet depositions, though they are harder to measure. It is possible that present measuring systems underestimate the magnitude of the problem of acid rain.

Acid depositions have drastically different effects in different locations. Some soils, like limestone, have plentiful calcium carbonate and silicates that are effectively able to neutralize the incoming hydrogen ions. Such soils generally have a pH of 5.0 or more and are said to be well "buffered." But poor, thin soils, such as those overlying granite or igneous rocks or noncalcareous sandstones, are already slightly acidic and have little ability to neutralize any additional acidity. Examples of the latter are found in the mountains of New England, the Appalachians, the Adirondacks, extensive regions of Quebec and Ontario in eastern Canada and in Scandinavia.

Having established what acid rain is, let us look at its effects—bearing in mind that these can be very complex and that there is much that is still unknown.

Sandra Postel, author of the Worldwatch Institute's publication *Air Pollution, Acid Rain, and the Future of Forests*, writes: "Trees derive their nutrition primarily from elements such as calcium, magnesium and potassium that are weathered from minerals in the soil. Acid deposition adds hydrogen ions to the soil, which displace these important nutrients."

This leaching out of nutrients is a serious matter. Calcium, for example, is an essential element for the vitality or growth of a tree. It is involved in cell formation and in the processes and structures that transport sugars, water and nutrients from the roots to the leaves. Magnesium is a vital element in photosynthesis and as a carrier of phosphorus, itself vital in the production of DNA. It is also an important constituent of seeds.

Apart from its action in washing away nutrients, increasing acidity can also leach out, or "mobilize," aluminum, which is normally present in an insoluble or nontoxic form in many soils. But it appears that at pH values below 5.0 aluminum leaches out and becomes toxic, leading to stunted root development and inhibiting the plant's take-up of calcium.

Other toxic heavy metals can also be leached out of the soil, but they may also be introduced from the atmosphere as a result of fossil-fuel combustion. These metals include lead, zinc, copper, cadmium, chromium, manganese and vanadium.

The end result, then, under certain circumstances, of burning coal and oil may be to remove some of the most important plant nutrients in the soil and replace them with a toxic cocktail of heavy metals. In addition to curbing tree growth, the synergistic combination of toxic metals also affects mosses, algae, nitrogen-fixing bacteria, fungi and earthworms.

The effect of dry deposition falling onto leaves is to leach nutrients such as calcium and magnesium out of the leaves themselves. It may also affect the waxy, protective surface area, and some tiny particles may enter into the leaves through the stomata.

Although most attention has been focused on damage in the East, many other parts of the country have been affected. Twenty-six eastern and 11

Contour lines show the estimated pH of precipitation. Rain is naturally slightly acidic at pH 5.6, while a neutral pH is 7. Lower numbers mean increased acidity.

western states contain areas sensitive to acid rain, and research by the U.S. Geological Survey indicates that alkalinity levels (a measure of the capacity to neutralize acid) are declining in surface waters at many locations in the north-central, midwestern and southeastern regions of the country. While the northeastern states face the most acute problem in the near term, the evidence suggests that in the longer term it may be a national issue.

International attention was first drawn to acid rain by Sweden, where widespread acidification of lakes was reported in the early 1970s. Currently, it is estimated that 18,000 Swedish lakes are acidified, 4,000 seriously, and 9,000 have had their fish populations affected. Dr. Orie Loucks (director of the Holcombe Research Institute of Butler University in Indianapolis) estimated in 1982 that 3,000 lakes and 25,000 miles of streams had been altered by acidic input in the eastern states.

Some of the most dramatic effects on forests have been observed in Europe. A survey in West Germany in 1983 revealed that an area of 9,800 square miles of forest, or 34 percent of the country's total, is damaged by air pollution. This includes about half of the world-famous Black Forest. Within this overall area, 2,162 square miles have been designated a "total damage area" in which complete loss of productivity is expected. The Germans, who face an economic cost of about $1.2 billion a year, are seriously worried about the loss of their forests.

Elsewhere in Europe, disturbing reports are filtering out of Poland, Czechoslovakia, East Germany and the Soviet Union, all suggesting massive forest damage. A recent report from the Netherlands indicates that pine and oak in some areas are seriously affected by acid rain. Since the soil on which Dutch forests grow is sand above an impermeable substratum of loess, and is among the most acid in Europe, it is not worth trying to replant. Switzerland has recorded damage to 14 percent of her forest trees, and points out that this could be potentially very serious because belts of trees above Alpine villages protect them against avalanches, landslides and floods.

Widespread visible effects on the scale observed in Europe have not yet been seen in North America, but there is mounting evidence that gives cause for concern—at the very least.

Dr. Robert Bruck, a plant pathologist at North Carolina State University, recently reported that red spruce and Fraser firs were dead or dying on the top of Mount Mitchell, North Carolina, the tallest peak on the eastern seaboard. Apparently there were few signs of any plant life reproducing there. Meanwhile, news is coming in from a number of other scientists of signs of tree-growth-rate decline in states ranging from Maine to Alabama. And it seems that the decline has unquestionably speeded up in the past 10 years.

The species most affected are conifers, though some deciduous trees are also experiencing adverse effects. Dr. Hubert Vogelmann, professor of botany at the University of Vermont, explains that this may be due in part to the fact that deciduous trees shed their leaves in the fall and so have a respite from airborne pollution during the winter months. Conifers, by contrast, have their needles bathed in acid deposition (if that is what it is) all year round.

Vogelmann is well-known for having reported some startling evidence of tree damage on Camels Hump, a high peak in Vermont's Green Mountains, in 1982. Now he and his colleagues have carried out further research that looks to be equally alarming.

"We have recently updated our study to 1983, and the new information confirms the trend we had already identified. We measured the biomass [the amount of living material above ground, including trunks, branches, etc.] of a number of tree species growing on Camels Hump, and we found that nearly all of them are going down.

"For example, the balsam fir has dropped from about forty-six thousand pounds per acre in 1965 to thirty-seven thousand in 1983. That's a twenty-percent decline. And the red spruce, one of the dominant species,

"DAMAGE IN THE GREAT SMOKIES, CATSKILLS AND ADIRONDACKS IS MOSTLY AT HIGH ELEVATIONS. THE CLOUD ZONE SEEMS TO BE THE COMMON LINK."

This marble maiden (top) in the Place de la Concorde may be a victim of acid rain.

Another pollutant, ground-level ozone, causes lesions on a grape leaf (middle).

The altered chemical mix of an Adirondack stream asphyxiates brook trout (bottom).