Paragraphs

Make your writing easy for the reader:

Set up expectations... and then meet them

A puzzle:

A bat and ball together cost $1.10,
and the bat costs $1 more than the ball.

How much is the ball?

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A puzzle:

A bat and ball together cost $1.10,
and the bat costs $1 more than the ball.

How much is the ball?

Answer: 10 cents?

A puzzle:

A bat and ball together cost $1.10,
and the bat costs $1 more than the ball.

How much is the ball?

Answer: 10 cents?

no... 5 cents!!

(Shane Frederick, 2002)

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A different puzzle:

A bat and ball together cost $1.10, and the bat costs $1.05.

How much is the ball?

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“Framing Effects”

(Daniel Kahneman, Princeton University)
Nobel Prize, 2002

The human mind comes to information with preconceptions and expectations; it easily falls into error or mis-interpretation

It is not only the *content* of the information that matters; *structure* matters as well

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equipment, and to Dr. G. E. R. Deacon and the captain and officers of R.R.S. *Discovery II* for their part in making the observations.

[1] Young, F. B., Gerrard, H., and Jevons, W., *Phil. Mag.*, **40**, 149 (1920).

[2] Longuet-Higgins, M. S., *Mon. Not. Roy. Astro. Soc., Geophys. Supp.*, **5**, 285 (1949).

[3] Von Arx, W. S., Woods Hole Papers in Phys. Oceanog. Meteor., **11** (3) (1950).

[4] Ekman, V. W., *Arkiv. Mat. Astron. Fysik. (Stockholm)*, **2** (11) (1905).

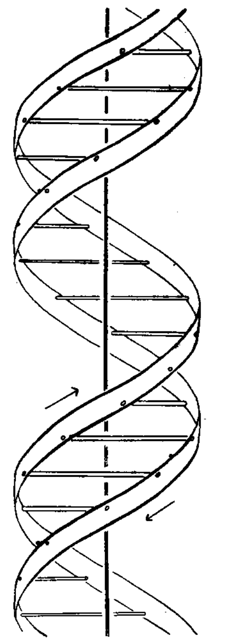
MOLECULAR STRUCTURE OF NUCLEIC ACIDS

A Structure for Deoxyribose Nucleic Acid

WE wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.). This structure has novel features which are of considerable biological interest.

A structure for nucleic acid has already been proposed by Pauling and Corey[1]. They kindly made their manuscript available to us in advance of publication. Their model consists of three intertwined chains, with the phosphates near the fibre axis, and the bases on the outside. In our opinion, this structure is unsatisfactory for two reasons: (1) We believe that the material which gives the X-ray diagrams is the salt, not the free acid. Without the acidic hydrogen atoms it is not clear what forces would hold the structure together, especially as the negatively charged phosphates near the axis will repel each other. (2) Some of the van der Waals distances appear to be too small.

Another three-chain structure has also been suggested by Fraser (in the press). In his model the phosphates are on the outside and the bases on the inside, linked together by hydrogen bonds. This structure as described is rather ill-defined, and for this reason we shall not comment on it.



This figure is purely diagrammatic. The two ribbons symbolize the two phosphate—sugar chains, and the horizontal rods the pairs of bases holding the chains together. The vertical line marks the fibre axis

We wish to put forward a radically different structure for the salt of deoxyribose nucleic acid. This structure has two helical chains each coiled round the same axis (see diagram). We have made the usual chemical assumptions, namely, that each chain consists of phosphate diester groups joining β-D-deoxyribofuranose residues with 3′,5′ linkages. The two chains (but not their bases) are related by a dyad perpendicular to the fibre axis. Both chains follow right-handed helices, but owing to the dyad the sequences of the atoms in the two chains run in opposite directions. Each chain loosely resembles Furberg's[2] model No. 1; that is, the bases are on the inside of the helix and the phosphates on the outside. The configuration of the sugar and the atoms near it is close to Furberg's 'standard configuration', the sugar being roughly perpendicular to the attached base. There is a residue on each chain every 3·4 A. in the z-direction. We have assumed an angle of 36° between adjacent residues in the same chain, so that the structure repeats after 10 residues on each chain, that is, after 34 A. The distance of a phosphorus atom from the fibre axis is 10 A. As the phosphates are on the outside, cations have easy access to them.

The structure is an open one, and its water content is rather high. At lower water contents we would expect the bases to tilt so that the structure could become more compact.

The novel feature of the structure is the manner in which the two chains are held together by the purine and pyrimidine bases. The planes of the bases are perpendicular to the fibre axis. They are joined together in pairs, a single base from one chain being hydrogen-bonded to a single base from the other chain, so that the two lie side by side with identical z-co-ordinates. One of the pair must be a purine and the other a pyrimidine for bonding to occur. The hydrogen bonds are made as follows: purine position 1 to pyrimidine position 1; purine position 6 to pyrimidine position 6.

If it is assumed that the bases only occur in the structure in the most plausible tautomeric forms (that is, with the keto rather than the enol configurations) it is found that only specific pairs of bases can bond together. These pairs are: adenine (purine) with thymine (pyrimidine), and guanine (purine) with cytosine (pyrimidine).

In other words, if an adenine forms one member of a pair, on either chain, then on these assumptions the other member must be thymine; similarly for guanine and cytosine. The sequence of bases on a single chain does not appear to be restricted in any way. However, if only specific pairs of bases can be formed, it follows that if the sequence of bases on one chain is given, then the sequence on the other chain is automatically determined.

It has been found experimentally[3,4] that the ratio of the amounts of adenine to thymine, and the ratio of guanine to cytosine, are always very close to unity for deoxyribose nucleic acid.

It is probably impossible to build this structure with a ribose sugar in place of the deoxyribose, as the extra oxygen atom would make too close a van der Waals contact.

The previously published X-ray data[5,6] on deoxyribose nucleic acid are insufficient for a rigorous test of our structure. So far as we can tell, it is roughly compatible with the experimental data, but it must be regarded as unproved until it has been checked against more exact results. Some of these are given in the following communications. We were not aware of the details of the results presented there when we devised our structure, which rests mainly though not entirely on published experimental data and stereochemical arguments.

It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material.

Full details of the structure, including the conditions assumed in building it, together with a set of co-ordinates for the atoms, will be published elsewhere.

We are much indebted to Dr. Jerry Donohue for constant advice and criticism, especially on interatomic distances. We have also been stimulated by a knowledge of the general nature of the unpublished experimental results and ideas of Dr. M. H. F. Wilkins, Dr. R. E. Franklin and their co-workers at

Watson & Crick

First paragraph:

WE wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.). This structure has novel features which are of considerable biological interest.

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Watson & Crick

Second paragraph:

A structure for nucleic acid has already been proposed by Pauling and Corey[1]. They kindly made their manuscript available to us in advance of publication. Their model consists of three intertwined chains, with the phosphates near the fibre axis, and the bases on the outside. In our opinion, this structure is unsatisfactory for two reasons: (1) We believe that the material which gives the

Watson & Crick

Third paragraph:

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Watson & Crick

Fourth paragraph:

We wish to put forward a radically different structure for the salt of deoxyribose nucleic acid. This structure has two helical chains each coiled round the same axis (see diagram). We have made the usual chemical assumptions, namely, that each chain consists of phosphate di-

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Watson & Crick

Fifth paragraph:

The structure is an open one, and its water content is rather high. At lower water contents we would expect the bases to tilt so that the structure could become more compact.

Overall structure:

1. We propose a structure for DNA

2. A structure proposed by X doesn't work because ...

3. A structure proposed by Y also fails

4. We propose a structure with helical chains etc. (gives details)

5. This structure is open...

A simple technique: topic sentences

Each paragraph should:
A) set up expectations, and then
B) fulfill them

- One sentence of a paragraph should state the main point; this is called the "topic sentence" and is *usually* the first sentence.
- Other sentences in the paragraph support or explore the point made by this topic sentence.

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Making Banking Boring
Paul Krugman, *New York Times*

First paragraph

Thirty-plus years ago, everyone knew that banking was, well, boring. When I was a graduate student in economics, only the least ambitious of my classmates sought careers in the financial world. Even then, investment banks paid more than teaching or public service — but not that much more.

Second Paragraph

<u>In the years that followed, of course, banking became anything but boring.</u> Wheeling and dealing flourished, and pay scales in finance shot up, drawing in many of the nation's best and brightest young people (O.K., I'm not so sure about the "best" part). And we were assured that our supersized financial sector was the key to prosperity.

A small portion of each paragraph makes its key point. The rest gives detail.

Write About Science WAS

Third Paragraph

Instead, however, finance turned into the monster that ate the world economy.

Even one sentence can be an effective paragraph

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The result of good topic sentences:

text reads as a sequence of claims, each supported by some evidence

Topic sentence: making the main point or claim
[Remainder of paragraph, giving evidence for this point, illustrating with examples, etc.]

Topic sentence: making another point or claim
[Remainder of paragraph, giving evidence for this point, illustrating with examples, etc.]

And so on...

Each topic sentence sends your reader forward with expectations of what they'll hear next

Write About Science WAS

Exercise:

A less obvious example

Write About Science WAS

Exercise

Write one short sentence capturing the main point or claim made by each of the following paragraphs. (Feel free to simply underline parts of the existing sentences if they already capture the main point or claim.)

The rise of biomathematics, which led John Maynard Smith to say, “if you can’t stand algebra keep out of evolutionary biology,” has been a runaway success. In many fields, empiricists continually struggle to keep up with and verify the assumptions and predictions of modellers.

An exception is the famously contentious topic of sympatric speciation — the process by which new species arise from coexisting as opposed to geographically isolated populations. There is growing evidence, particularly from lakes full of closely related fish species, that sympatric speciation does occur in nature. But models of the phenomenon have stubbornly concluded that evolution of sexual isolation without spatial isolation seems very unlikely.

At first glance, sympatric speciation looks straightforward. If a lake contains two potential resources — say, large or small prey — then large or small predatory fish will do well while medium-sized fish will be at a disadvantage. This disadvantage to intermediates, termed ‘disruptive selection’, creates pressure for divergence into two populations of distinct ecological types.

In sexual populations, the stumbling block preventing sympatric speciation is that mating between divergent ecotypes constantly scrambles gene combinations, creating organisms with intermediate phenotypes (physical characteristics). This mixing can be prevented only if there is assortative mating, in which pairings between similar individuals are more common. With disruptive selection, this pairing pattern is selectively favoured, because it reduces the production of offspring that are less well adapted to their environment. But there is a barrier to the evolution of assortative mating — recombination, the shuffling of genes during gamete formation, which means that genes for mating preference and ecotype (size for instance) may get mixed up whenever an occasional mating between different types occurs. This creates individuals with a preference for the opposite ecotype, increasing gene flow between types and opposing speciation.

Good topic sentences bring out the logical skeleton of the argument; they turn it into a STORY...

1. Bio-mathematics has been a runaway success
2. An exception is sympatric speciation
3. At first glance, it seems simple to understand...
4. In sexual populations, the problem is...

Good topic sentences bring out the logical skeleton of the argument; they turn it into a STORY...

1. Bio-mathematics has been a runaway success

2. An exception is sympatric speciation

3. At first glance, it seems simple to understand...

4. In sexual populations, the problem is...
   TERRIBLE TOPIC SENTENCE!!!
   THIS IS SUPPORTING INFORMATION...

Write About Science WAS

Good topic sentences bring out the logical skeleton of the argument; they turn it into a STORY...

1. Bio-mathematics has been a runaway success

2. An exception is sympatric speciation

3. At first glance, it seems simple to understand...

4. In fact, it is not so simple. In sexual populations, the problem is...

Write About Science WAS

A simple technique: topic sentences

- One sentence of a paragraph should state the main point; this is called the "topic sentence" and is *usually* the first sentence.
- Other sentences in the paragraph support or explore the point made by this topic sentence.

Write About Science WAS

Another example

Cooperation, Reciprocity and Punishment in Fifteen Small-scale Societies

Joseph Henrich, Robert Boyd, Samuel Bowles, Colin Camerer
Ernst Fehr, Herbert Gintis, and Richard McElreath[1]

January 13, 2001

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First paragraph

1. Introduction

Recent investigations have uncovered large, consistent deviations from the predictions of the textbook presentation of *Homo economicus*. One problem appears to lie in economists' assumption that individuals are entirely self-interested; in addition to their own material payoffs, many experimental subjects appear to care about fairness and reciprocity...

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Second paragraph

Fundamental questions remain unanswered. Are the deviations from the canonical model evidence of universal patterns of behaviour, or do the individuals' economic and social environments shape behaviour?...

Third paragraph

<u>Existing research cannot answer such questions because virtually all subjects have been university students.</u>
... To address the above questions, we and our collaborators undertook a large cross-cultural study... in twelve countries on four continents...

Fourth paragraph

We can summarize our results as follows. First, the canonical model is not supported in any society studied. Second, there is considerably more behavioural variability across groups than had been found in previous cross-cultural research and...

Exercises on topic sentences

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Exercises on topic sentences
Choose the best among the several topic sentences listed for each paragraph below.

1. The first is the wear-and-tear hypothesis that suggests the body eventually succumbs to the environmental insults of life. The second is the notion that we have an internal clock which is genetically programmed to run down. Supporters of the wear-and-tear theory maintain that the very practice of breathing causes us to age because inhaled oxygen produces toxic by-products. Advocates of the internal clock theory believe that individual cells are told to stop dividing and thus eventually to die by, for example, hormones produced by the brain or by their own genes.

a. There are two broad theories concerning what triggers a human's inevitable decline to death.
b. Some scientists believe that humans contain an "internal time clock" which forces them eventually to die.
c. We all must die some day.
d. My biology professor gave an interesting lecture Thursday.

Exercises on topic sentences
Choose the best among the several topic sentences listed for each paragraph below.

2. The strictest military discipline imaginable is still looser than that prevailing in the average assembly-line. The soldier, at worst, is still able to exercise the highest conceivable functions of freedom -- that is, he or she is permitted to steal and to kill. No discipline prevailing in peace gives him or her anything remotely resembling this. The soldier is, in war, in the position of a free adult; in peace he or she is almost always in the position of a child. In war all things are excused by success, even violations of discipline. In peace, speaking generally, success is inconceivable except as a function of discipline.

a. Soldiers need discipline.
b. We commonly look on the discipline of war as vastly more rigid than any discipline necessary in time of peace, but this is an error.
c. Although soldiers are not always disciplined, they serve an important social function in wartime.
d. In times of peace, soldiers often convert easily from wartime pursuits to the discipline necessary to compete in even the most competitive marketplace.

Exercises on topic sentences
Choose the best among the several topic sentences listed for each paragraph below.

3. Indeed, quantitative records of many different kinds of human activity are already being gathered and stored in enormous databases. E-mail and phone records document our social and professional interactions; travel records and GPS navigation systems capture our travel patterns and physical locations; credit-card companies maintain records of our shopping and entertainment habits. Although in the wrong hands, these data sets could represent Orwellian tools of power, for scientists they offer incredible insights into human behaviour. Combine this capability with the sophisticated tools of network theory, which analyzes relations between millions of individuals, and you get a glimpse of an unprecedented opportunity to quantify human dynamics.

a. The gathering of email data by large corporations represents a threat to privacy.
b. Human behaviour cannot be captured in simple or even complex mathematical models.
c. Modern technology is rapidly establishing the tools for a mathematical understanding of a great deal of human behaviour.
d. Social science had not yet reached the level of sophistication of the natural sciences.

Exercises on topic sentences
Choose the best among the several topic sentences listed for each paragraph below.

4. In Montreal, a flashing red traffic light instructs drivers to careen even more wildly through intersections heavily populated with pedestrians and oncoming vehicles. In startling contrast, an amber light in Calgary warns drivers to scream to a halt on the off chance that there might be a pedestrian within 500 meters who might consider crossing at some unspecified time within the current day. In my home town in New Brunswick, finally, traffic lights (along with painted lines and posted speed limits) do not apply to tractors, all terrain vehicles, or pickup trucks, which together account for most vehicles on the road. In fact, were any observant Canadian dropped from an alien space vessel at an unspecified intersection anywhere in this vast land, he or she could almost certainly orient him-or-herself according to the surrounding traffic patterns.

a. People in Calgary are careful of pedestrians.
b. Although the interpretation of traffic signals may seem highly standardized, close observation reveals regional variations across this country, distinguishing the East Coast from Central Canada and the West as surely as dominant dialects or political inclinations.
c. People in Montreal drive faster than people in Alberta, and Maritimers generally don’t pay any attention to traffic signals at all.
d. Canadians do not follow traffic signals properly.

Making contact with the real world

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NEWS & VIEWS

doi:10.1038/nature12837

SYSTEMS BIOLOGY

How bacteria choose a lifestyle

In a bacterial population, some cells stay single and motile, whereas others settle down and form chains. A study now investigates the mechanisms that determine these outcomes.

JAMES C. W. LOCKE

Cells can switch identity several times during development. How do they decide to switch? There is much debate about the extent to which identity switching is a cell-autonomous decision as opposed to being driven by environmental signals. In a paper published on *Nature*'s website today, Norman *et al.*[1] take an unusual approach to address this issue. They watch the soil bacterium *Bacillus subtilis* growing in an unchanging environment in which switching cannot be driven by extracellular signals. They focus on a simple switch — the transition from a single-cell swimming (motile) state to a sessile state that allows the bacteria to form a chain. Their findings provide invaluable insight into how an individual cell makes up its mind.

The authors grew *B. subtilis* in a microfluidic device consisting of several channels, each designed to support bacterial growth for days in a constantly replenishing medium that washes away any extracellular signals[2]. The bacterial strains studied express fluorescent 'reporter' proteins for both motile and sessile states, enabling the researchers to quantify the frequency and duration of cell-fate switching events under constant environmental conditions.

Norman and colleagues' detailed and precise characterization of hundreds of switching events reveals a critical difference in the transition from the motile to the sessile state and the switch in the other direction. The shift from the motile to the sessile state seems to be completely random and independent of how long the bacterium has been in the motile state. This motile state, therefore, is 'memoryless'.

The switch from the sessile to the motile state, however, is not random and is tightly timed: cells remain in the sessile state for roughly eight generations. The authors suggest that this memory serves a cellular function, ensuring that switching to the motile state, which breaks the chain almost immediately, does not occur too soon or with too much delay, which could result in some chains overflowing with millions of cells. The transition to the sessile state probably represents a trial period of multicellularity, which could be reinforced by environmental signals to commit the cells to forming a biofilm.

Norman and co-workers also explore the molecular mechanism that controls the cell-fate switch. It seems to involve a simple circuit consisting of only three proteins[3] (Fig. 1). Specifically, the protein SinR represses the gene encoding another protein, SlrR; in turn, SlrR binds to and titrates SinR. Thus, these two proteins form a double-negative feedback switch. When SinR wins, the cell enters a motile state; when SinR loses, the cell becomes sessile. The third protein, SinI, affects which outcome wins by binding to, and inactivating, SinR.

The circuit seems to be modular, as the authors find that SinI is responsible for the memoryless entry into the sessile state. Once the bacteria are in the sessile state, however, SinI is no longer relevant, and the memory is set by the SlrR–SinR feedback loop. Such modularity has also been observed in another *B. subtilis* circuit that controls a developmental switch. Under stress conditions, *B. subtilis* can transiently enter a competent state, allowing it to take up external DNA[4]. The core circuitry that controls entry into the competent state has only a few components, similar to the SlrR–SinR–SinI network. The competence circuit is modular because one component regulates the frequency of transitions into the competent state, whereas another component determines how long a cell remains in this state[4].

It is unclear what advantage, if any, such modularity has for the cell. Can having independent control of the initiation and duration of differentiation events enable the cell to adapt to independent selective pressures during evolution? And it remains to be seen whether such modularity is a general feature of circuits that control cell-identity switching.

The authors also raise questions about how the SlrR–SinR–SinI circuit controls cell-fate switching in *B. subtilis*. How noise, or variability, in one of the circuit components drives initiation into a sessile state remains unclear. Although initiation requires SinI, it is not known which circuit component exhibits random fluctuations to drive the random switch into the sessile state, or how these fluctuations are generated. It would be interesting to test the hypothesis that memory in state switching allows a trial window of multicellularity that is reinforced by environmental signals. One approach could be to examine what effect extending or reducing the memory of the sessile state has on biofilm formation.

Norman and colleagues' SlrR–SinR–SinI circuit joins a growing list of bacterial simple genetic circuits that have been shown to control surprisingly complex cellular dynamics. Such circuits often consist of only three or four proteins but can generate pulses[5], excitable dynamics[4] and robust oscillations[6]. Might simple genetic circuits generate a similar wealth of regulatory dynamics in plants and animals? Results in cows suggest[7] that the

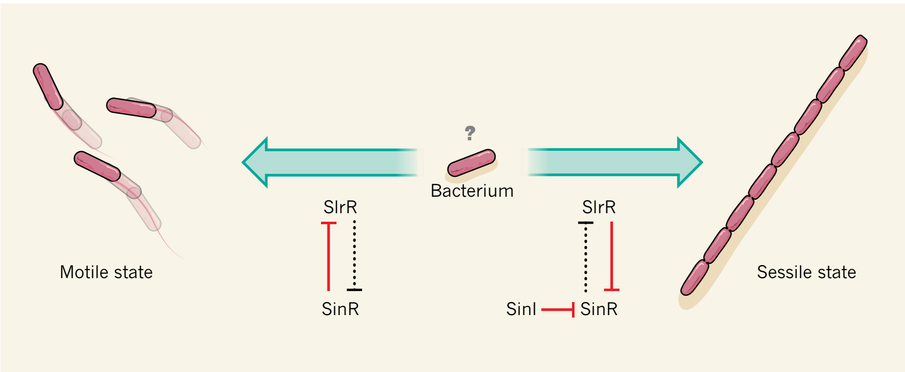

Figure 1 | To be sessile or to swim. Norman *et al.*[1] examine how single cells of the bacterium *Bacillus subtilis* choose between a motile (swimming) state and a sessile state. This choice is controlled by a simple double-negative feedback circuit involving three proteins: SinR represses SlrR, which represses SinR in turn. When SinR dominates, transition to the motile state occurs, whereas when SlrR dominates, the cells become sessile and form chains. A third protein, SinI, can initiate the switch to the sessile state by binding to and inactivating SinR.

First paragraph

Cells can switch identity several times during development. How do they decide to switch? There is much debate about the extent to which identity switching is a cell-autonomous decision as opposed to being driven by environmental signals. In a paper published on...

Here these two sentences act like one: “Cells often switch during development, but the mechanisms that control switching remain unknown." Then the next sentence backs this up and adds detail ...

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Second paragraph

The authors grew B. subtilis in a microfluidic device consisting of several channels, each designed to support bacterial growth...

Here there is NO topic sentence! It could have been something like "the study rests on a clever experimental design," but this isn't really necessary... the authors do without...

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Third paragraph

Norman and colleagues' detailed and precise characterization of hundreds of switching events reveals a critical difference in the transition from the motile to the sessile state and the switch in the other direction. The shift from the motile to the sessile state seems to be...

A clear topic sentence, then supporting detail...
Later paragraphs all have this structure

American Scientist online
THE MAGAZINE OF SIGMA XI, THE SCIENTIFIC RESEARCH SOCIETY

FEATURE ARTICLE

The Science of Scientific Writing

George D. Gopen & Judith A. Swan

If the reader is to grasp what the writer means, the writer must understand what the reader needs.

This article was originally published in the November-December 1990 issue of American Scientist.

Science is often hard to read. Most people assume that its difficulties are born out of necessity, out of the extreme complexity of scientific concepts, data and analysis. We argue here that complexity of thought need not lead to impenetrability of expression; we demonstrate a number of rhetorical principles that can

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