THE PERSONA OF DR. LEWIS THOMAS:

A STUDY OF THE LIVES OF A CELL

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PREFACE

Traditionally scientists have viewed the role of scientific writers as unobtrusive. They, therefore, contend that the persona of scientific writers must be objective, unemotional, and impartial. Yet, scientists and rhetoricians of the past twenty years have begun to question the application of this persona to all kinds of scientific writing. Dr. Lewis Thomas, as a physician writing to popular audiences, illustrates in The Lives of a Cell how a more personable, involved persona adds interest and makes scientific subjects approachable without compromising the credibility of his professional voice.

I wish to express gratitude to the friends and family members who have encouraged me while working on this dissertation. A special thanks goes to my advisor, Dr. Sherry Southard who willingly gave her time, help, and direction. I also thank my other committee members--Dr. Thomas Warren, Dr. Bruce Southard, and Dr. Marvin Keener for their prompt and helpful responses to each chapter.

For giving me undisturbed time at my computer, and for demanding occasional, needed interruptions, I thank my two-year-old daughter Megan. For his time, support, and assistance,

I thank my husband Warren, who not only gave moral support, but also typed and alphabetized lists and provided his medical expertise. I am proud to say that this paper has been another of our many joint endeavors.

A special thanks goes to Ms. Stephanie Hemmert, Dr. Lewis Thomas' secretary, who gave important bibliographic information and to Dr. Thomas himself, who took time from his busy schedule to grant me a valuable interview.

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CHAPTER I

INTRODUCTION

Lewis Thomas himself confirms that identifying persona is difficult, for when asked to describe his persona, he replied, "I didn't know I had one!" (Thomas, Interview). Yet in talking with him, I discovered the same persona that I found in the book, that of a personable, knowledgeable doctor who has fun with science. He indirectly described his persona when he stated his purpose in writing The Lives of a Cell: "I wanted the essays to be fun to read." In that statement he suggests his persona or his attitude toward both subject and audience: that he will have fun with science and share that fun with his audience. Although Thomas has published over 200 articles for scientific journals, he regards that kind of scientific writing that obscures all evidences of the author, as "non-writing. . . It is hard reading, hideous prose, a stereotyped way of giving fact after fact" (Thomas, Interview). This kind of writing is further described by Stewart as

> the rigid exclusion of everything that does not bear directly upon the subject. The pains which scientists take with language and logic are also taken with the point of view from which their reports are written. The reader is not

> encouraged to think of the writer as an individual having the emotions, prejudices and interests common to all men. (157-58)

Yet, what impresses the reader about Thomas' writing is the strong sense of the writer, his "emotions, prejudices and interests" which he makes known to be common to all men. Moreover, he writes within the context of other twentieth-century scientists, like Einstein and Kuhn, who recognize the influence that scientists have on creating what we know as reality. They propose that reality is an ongoing creation of the scientist rather than some absolute physical reality. Hence, researchers on writing and scientific writers of the past twenty years have begun to recognize the influence of scientists on their work and writing. In addition, the view of science as a rhetorical activity and the rise of popularized scientific writing have caused scientific writers to redefine their persona.

Purpose of the Dissertation

An issue that naturally follows from this interest in the persona of scientific writers is how persona is created. Do scientists consciously create a persona that will serve their particular purposes? Thomas replies that he does not. The fact that he is unaware of his persona indicates the kind of persona Thomas communicates in <u>The Lives of a Cell</u>, for he openly shares

himself and his enthusiasm for life with no pretense. What we see is the man as he is, plainly a man enamored with life and intrigued by humankind. In this dissertation, I explore how Thomas communicates this persona through the organization, content, and style of The Lives of a Cell.

Justification for the Dissertation

In this paper, I attempt to delineate specifically how Thomas' persona enters his text in The Lives of a Cell. While many studies indicate a changing view of the scientific persona when scientists write to lay audiences, few have analyzed specifically how writers create their personae. In addition, I have chosen to analyze the persona of Thomas, for he develops an intimacy with his audience, and a person-oriented response to science, not seen in popularizers such as Gould and Sagan.[1]

The writing of Dr. Lewis Thomas offers a credible example for this study; both the sciences and humanities have recognized him for his popularized writing. In 1975, both the Science and the Arts-and-Letters panels nominated The Lives of a Cell for the National Book Award (Lounsberry 7).[2] The book has sold over 300,000 copies and has been translated into eleven languages (Gray 87). Moreover, Dr. Thomas comes to his popularized writing from an in-depth background in medical teaching, research, and administration.

Presently a Scholar-in-Residence at the Cornell University Medical College and President Emeritus of Memorial Sloan-Kettering Cancer Center, Thomas obtained his undergraduate training at Princeton University and his medical degree from Harvard. He has served on the faculties of five schools of medicine, of which he has been chairman of the department of medicine and pathology at New York University, chairman of pathology at Yale University, and dean of both (Thomas, Interview).

In addition to devoting much time to teaching, research, and administration, Thomas has been writing for scientific journals since 1941, with the majority of his popularized writing beginning in 1970. (See Appendix A for a complete bibliography of his works.) He has published over 200 scientific papers on virology, immunology, experimental pathology, and infectious disease. He also authored a column in the New England Journal of Medicine, "Notes of a Biology Watcher," from 1971 to 1980 ("Thomas," Contemporary). The majority of the essays published in this column comprise his popularized writing that has been collected in four books: The Lives of a Cell (1974), The Medusa and the Snail (1979), The Youngest Science (1983), and Late Night Thoughts on Listening to Mahler's Ninth Symphony (1984).

Distinguishing his popularized writing are the optimism, wit, and imagination with which he discusses the

symbiotic relationship of man and nature. Hence, his persona becomes an essential element in fulfilling his purpose: to humanize science for lay readers (Dowdy 15).

Scope of the Dissertation

My focus in this dissertation is persona in the popularized scientific writing of Dr. Lewis Thomas. Throughout this paper, I do not include works on technical writing unless an author uses the general label of technical writing to designate writing done in technology as well as in the sciences. I have also confined my study to the theories and practice of persona in popularized scientific writing and do not discuss methods for teaching the persona of scientific writing.

To establish a context for Thomas' use of persona, I begin my study by reviewing the scholarship on persona in scientific writing. I review the literature of the past twenty years because this is the period in which Thomas has done the majority of his popularized writing, and this is the period in which researchers have begun to directly address this topic of persona.

In reviewing the literature on persona in scientific writing, I find a variety of approaches to and terminology for this subject. Therefore, I have included studies that use the terms <u>ethos</u>, <u>voice</u>, and <u>persona</u> interchangeably as the personal qualities of the author communicated through the

text. I have also included information on persona found under such related terms as _personality_, _subjectivity_, and _creativity_. I do not use _point of view_ as a term synonymous to _persona_, for _point of view_ is defined as the attitudes of a writer exhibited through the use of first, second, or third person (Brusaw 459) and does not encompass such features as diction, syntax, and analogies that can also communicate persona. In this review of literature, I also show how persona is created through the organization, content, and style of both scientific writing and popularized scientific writing. I then focus on one popularization of science, Thomas' _The Lives of a Cell_, to show how Thomas creates his persona through organization, content, and style.

Definitions

The following definitions clarify my use of the terms that are essential to this study.

While it is beyond the scope of this dissertation to give a complete definition of scientific writing, popularization of science, or technical communication, I distinguish these terms for the purpose of my discussion. My research in scientific writing reveals that researchers often use the terms _scientific writing_ and _technical writing_ loosely. They often use _technical writing_ as a broad term that encompasses the writing done in both science and technology. However, in this study, I am

interested in scientific writing as a product of its particular culture that encourages specific forms, purposes, thought processes, and stylistic devices. Hence, while technical writing stresses instructions and descriptions, scientific writing relies more on summaries and lab reports (Sparrow and Cunningham 2). Also, while technical writing tends to have a broader audience and is more application-oriented, scientific writing has a more select audience and is more truth-oriented. Although both kinds of writing encourage inductive organization, scientific writing relies more heavily on drawing inferences (Sparrow and Cunningham 2).

In this dissertation, I further distinguish between scientific writing and popularized scientific writing. I refer to scientific writing as the reporting of empirical data on a scientific subject to scientists.[3] Scientific writing may, in addition, be distinguished by particular stylistic techniques such as objectivity, noun strings, nominalizations, passive voice, long sentences with subordinate clauses, and Latinate words (Schindler 5-8). Popularized scientific writing seeks to bring science into the sphere of human experience (Bowen and Mazzeo 4). Because the audience of popularized scientific writing has little background in science, popularizers rely less on reporting empirical data than on discussing more philosophical observations about science. Moreover, the style of popularized scientific writing comes closer to the style of conversational

language (Gastel 11). As a result, writers use more personal pronouns, more casual diction, shorter sentences, and fewer of the conventions of scientific style, such as nominalizations, passive voice, and noun strings.

Other terms that need further distinction are ethos, voice, and persona. Generally, these terms are used interchangeably to refer to the personal qualities of the writer that appear in his or her writing. Aristotle has long provided the foundation for studies of ethos, although his emphasis in The Rhetoric is on speech rather than on writing. Aristotle describes ethos as the "sense of a good disposition or habit of choice" (xxii). To show their disposition, speakers establish intelligence, character, and good will. Aristotle further isolates ethos as the "most potent of all means of persuasion" but cautions speakers that they should not rely on character alone. The message itself should also create trust. Closely following Aristotle's concept of ethos is Edward P. J. Corbett's definition in his Classical Rhetoric for the Modern Student. He contends that people consist of more than reason, that they consist also of passion and intellect and "must deal with matters about which certainty is impossible" (93). The writer, then, impresses the audience by portraying sound sense (grasp of the subject), moral character (abhorrence of unscrupulous tactics), and good will (interest in the audience).

Voice signifies the equivalent to Aristotle's ethos in a work of persuasive rhetoric and also suggests the traditional rhetorician's concern with the importance of the physical voice. The writer's voice gives the sense of a pervasive presence, a determinate intelligence and moral sensibility which has selected, ordered, and expressed the materials of the text (Abrams 132). Anitra Sheen similarly relates voice to the role that the writer assumes at the onset of writing. She further explains that this voice, communicated largely through style, defines the relationship of the writer to both subject and reader (79).

Persona was the Latin word for the mask used by actors in the classical theater. Thus, this word came into use in literary criticism as a term that distinguished a created speaker in fiction from the writer of the narrative. However, in non-fiction writing such as scientific writing, persona, like ethos and voice, is used interchangeably to refer to the personal qualities and attitudes of writers as expressed in their writing (Abrams 132).

Persona is often discussed within the context of rhetoric, a term that has elicited various meanings throughout history. Michael Leff observes that rhetoricians traditionally have defined their discipline by distinguishing between rhetorical and poetic objects. Rhetoric thus applies to the literal and persuasive, poetic to the figurative and fictional. Rhetoric produces

"effects beyond the act" while poetics exercises symbolic action only for itself (88). Leff adds that recent scholarship rejects the dichotomy between communication and knowledge as rhetoric embraces a humanistic concept of rhetoric as a way of knowing. Leff's survey of rhetoric reveals a humanistic, functional concept of rhetoric that is appropriate for scientific writing. Other researchers, such as Halloran, Overington, and Wander, confirm that science and rhetoric both follow recent theories of reality in placing more emphasis on how scientists' and writers' personae shape the reality they communicate.

Plan of Development

I begin my study of persona in Chapter II by reviewing the literature of the past twenty years on persona in scientific writing and popularized scientific writing. In this chapter, I concentrate on the causes for the recent interest in persona, the contemporary definitions of persona in scientific writing, and the ways persona is created in a scientific text.

In Chapters III through V, I analyze Thomas' persona in The Lives of a Cell. In my interpretation of his persona in these chapters, I am influenced significantly by the explanations provided by Dr. Thomas in a telephone interview. In Chapter III, I discuss how the organization and form of the essay contribute to Thomas'

personal ethos. I isolate two kinds of organizational patterns, organic and straw man, and give examples of each, discussing them in detail. The essay form likewise allows for considerable personalism in the content of Thomas' essays. Hence, Chapter IV focuses on how Thomas' exploratory and human responses to scientific subjects portray a scientist who is personally involved in the concerns of mankind. In Chapter V, I use both computer analysis and my own search of various stylistic characteristics to identify those characteristics that communicate his person-oriented voice. In Chapter VI, I summarize and conclude the dissertation. I suggest areas for further research on persona in scientific writing, popular scientific writing, and the other writings of Lewis Thomas and give implications for the study of persona in scientific writing.

Notes

[1] I base this observation on my reading of Gould's The Panda's Thumb and Sagan's Broca's Brain. The subject matter of both books is more technical and further removed from the experiences of common people than is the subject matter of Thomas' The Lives of a Cell. In Gould's book the reader should be somewhat knowledgeable about Darwin and evolution to fully appreciate the many associations he makes between evolution and such subjects as the brain, Mickey Mouse, and the panda's thumb. Sagan similarly includes a higher level of technical detail than does Thomas, in such chapters as "Venus and Dr. Velikovsky," "Norman Bloom, Messenger of God," "The Past and Future of American Astronomy," and "Experiments in Space." Thomas, on the other hand, speaks primarily of those things that comprise the basics of human life, things we all share in common, like words, music, mitochondria, cells, and organelles. Moreover, when discussing scientific subjects, Thomas uses examples to which people can readily relate, such as ants and termites. He is not as highly allusive as Gould who refers to subjects and people that may not be familiar to a popular audience, such as Lamarck, Odysseus, Kant, Toscanini, and a plethora of scientists and researchers. In

both books, the essays are longer than are Thomas', and the language appears to be more learned and technical. Although both Gould and Sagan use many of the characteristics of popularized writing that Thomas uses, the more technical subject matter, allusive, learned kind of writing found in The Panda's Thumb and Broca's Brain do not communicate the intimacy and personalism found in Thomas' The Lives of a Cell.

[2] The National Book Awards (NBA) is a not-for-profit charitable and education institution with a two-part program: to honor American fiction and non-fiction writers with $10,000 and to develop a literacy media program to generate interest in contemporary books and writers ("National" 14). The two yearly awards are made publicly and are chosen by a publicly known group of jurors (Baker, John F. 9).

[3] According to the General Science Index, subject areas regarded as scientific are astronomy, atmospheric science, biology, botany, chemistry, earth science, environment and conservation, food and nutrition, genetics, mathematics, medicine and health, microbiology, oceanography, physics, physiology and zoology.

CHAPTER II

PERSONA IN CONTEMPORARY SCIENTIFIC WRITING: A REVIEW OF THE LITERATURE

One of the first questions that inevitably arises when studying the more subjective kind of persona that Lewis Thomas creates is how such a persona could emerge within a discipline that has long revered objectivity. Although the lay audience to which Thomas writes might partially explain his more personal kind of writing, he still communicates scientific information that has long demanded objectivity. To help explain the recent changes in the perspective toward persona in scientific writing, I turn to the significant body of literature that has, over the past twenty years, addressed directly the issue of persona in scientific writing[1]--both how it has developed and what it is today. Thus, I first review the literature that explains how such a seemingly divergent scientific persona could emerge within a tradition long devoted to objectivity. I then review the literature that explains the current theories of persona in scientific writing and show how persona is created in scientific writing. My purpose in reviewing this literature is to show that

Dr. Thomas' creation of persona does not occur in isolation, only for his specific purposes, but is acknowledged and supported by a general trend in scientific writing that has begun to alter its stance toward extreme objectivity.

Why Persona in Scientific Writing Has Changed

Affecting scientists' views toward objectivity are new theories of reality, developments in rhetoric, and the rise of popularized science. These developments have shifted the focus in scientific writing from an absolute physical reality to a more personal, humanistic view of the scientist who contributes to the creation of reality and, hence, affects the communication of it.

Theories of Reality

Since the beginnings of modern science during the late Renaissance, scientists have viewed their role as passive observer and recorder of physical reality. Furthermore, scientists considered only those things that were experienced by the senses as real. In essence, this view of reality survived until the mid-twentieth century. As Tessman notes, seventeenth-century scientists used metaphors and analogies to describe their ideas vividly and precisely (20). In the eighteenth century, scientists wrote as if

objectivity and human involvement could both exist in science, for they wrote about men doing experiments for the good of mankind. The nineteenth-century scientists returned to the belief in only an objective reality, manipulating language to avoid imagery and words that indicated any human involvement. In the twentieth century, scientists have begun to view the manipulation of language as meaningless because of growing doubts about reality (Tessman 20). Contributions by such scientists and philosophers as Einstein, Popper, and Kuhn reflect the growing trend in contemporary theory to believe that there is no objective truth and to view reality as the scientist's creation rather than as objective truth.

Einstein attributes this change in the conception of reality to Maxwell's work on electromagnetic phenomena. In "Maxwell's Influence on the Evolution of the Idea of Physical Reality" (1954), Einstein notes that before Maxwell, people conceived of physical reality as material points, whose changes consist of motions. After Maxwell, they considered physical reality to be represented by continuous fields that were not mechanically explicable. Einstein views this change in the conception of reality as the most profound one in physics since Newton. He adds in <u>The World as I See It</u> (1935) that the reality of the thing observed is relative to the observer. In formulating a theory, the scientist draws neither from external reality or <u>a priori</u> principles.

Instead, the scientist develops a scientific theory by a creative act of imagination.

Karl Popper refutes the traditional structure of reality in science by arguing against essentialism in Objective Knowledge (1972). Popper contends that scientists must give up the essentialist view that in everything there is an essence, an inherent nature which causes it to be what it is. This view has led essentialists to shun relational properties, such as gravity, and to believe that only inherent qualities satisfactorily explain a thing's behavior. Though to Popper a scientist can never describe an ultimate essence by universal laws, scientists can still probe deeper into structures of the world that are more and more essential. Hence, the aim of the scientist is not to discover absolute certainty, but to discover better and better theories.

To Einstein's and Popper's views on scientific reality, Thomas Kuhn adds the dimension of the paradigm. He defines paradigm in The Structure of Scientific Revolutions (1970), as what the members of a scientific community share. Kuhn thus places importance, not on some observed physical reality, but on the group of scientists who must approve an idea before it is accepted as a scientific reality. Thus Kuhn, like Einstein and Popper, suggests that creativity, rather than objectivity, is the acceptable response to reality.

The Rhetorical View of Science

Rhetoric and science exhibit significant parallels in their changing perception of objectivity and reality. Rhetoric, as well as science, is moving away from the Aristotelian view of speakers/writers as passive observers of given truths, to the current perception of speakers/writers as active creators of the reality they communicate (Samuels 7). Thus, rhetoricians now apply cognitive theory to rhetoric, to explore how writers filter, select, and organize the information they communicate (Flower and Hayes 208). Furthermore, rhetoricians are becoming more concerned with how the attitudes and emotions of writers affect the way they filter, select, and organize information (Brand 6). In light of recent cognitive theories and current views of reality, the scientific world of verifiable facts can no longer be easily distinguished from the world of personal attributes and values. In the works that follow, the authors portray science, not as a depersonalized, isolated activity, but as a humanized, rhetorical endeavor.

Kuhn's influence is evident in several of the key articles on the rhetorical nature of science, as researchers observe the influence of the community of scientists on the acceptance of scientific information. In "Technical Writing and the Rhetoric of Science" (1978), S. Michael Halloran captures the essence of scholarship on the

rhetoric of science with his observation that "the test of scientific schema is as much the degree to which it wins the agreement of other scientists as the degree to which it coincides with observed physical reality" (80). He, like Overington, Wander, and Watson see human encounter as essential to human knowing. Overington, in "The Scientific Community as Audience: Toward a Rhetorical Analysis of Science" (1977), proposes a four-part rhetorical construct of generating scientific knowledge: scientists as speakers, research situations as the context, results as arguments, and audience as respondents who determine the status of scientific knowledge. Overington thus shows how "individual beliefs become privileged knowledge through persuasion" (161). In "The Rhetoric of Science" (1976), Wander also notes the significance of persuasion to the acceptance of scientific information. He contends that reports function more to persuade than to advance scientific knowledge. Scientists accept reports when they have passed peer review; hence, Wander concludes that persuasion holds such significance to the advancement of scientific knowledge that scientists pose as scientists, but in reality function as rhetoricians whose ethos becomes critical.

James Watson agrees that advancing scientific information is not the primary concern of many scientists. Thus, in his account of the discovery of DNA, he attempts to recreate his impressions of relevant events and

personalities rather than record "the many facts I have learned since the structure was found" (3). By presenting a scientific discovery from this perspective, he hopes to clarify how science is often "done," for he finds that scientific research does not follow a prescribed pattern, but varies "almost as much as human personalities" (3).

Other scientists and researchers likewise argue for the humanistic value of science and scientific writing. Carolyn Miller refutes the claim made by logical positivists that sensory data are the only permissible bases for knowledge and that "the only meaningful statements are those which can be empirically verified" (612). Logical positivists attempt to devise an "observation language" that assumes a materialistic reality and minimizes personal and social interference. In this epistemology, language is a distraction to science; scientific writing, then, becomes a "series of maneuvers for staying out of the way" (613). As a result, writers consider only the relationship of the reader to reality and disregard the relationship of the reader to the writer. Miller welcomes a new epistemology that "makes human knowledge thoroughly relative and science fundamentally rhetorical" (615). This epistemology holds that facts do not exist independently; they are human constructions.

Gunther S. Stent, a molecular biologist, adds that a recent phenomenon in science is the recognition that the "facts" of science are not objective givens but are rather "thought collectives." In his preface to The Double Helix (1980), Stent contends that Watson's work has contributed most to the demise of the traditional view of science as an autonomous exercise of pure reason by "disembodied selfless spirits" (ix). He contends that scientists take a more personal perspective toward the history of science and adds that feelings, social interactions, and irrational attitudes have a more prominent role in advancing knowledge than the traditional view suggests. He points out that this more personal perspective began in the 1930s with the writings of Ludwik Fleck but did not gain widespread public recognition until the 1960s with the writings of Paul Feyerabend,[2] Thomas Kuhn, and James Watson.

This more humanistic, rhetorical view of science inevitably affects the current perspectives on the scientist's persona. John Knapp explores the scientist's personality and its relationship to cognition in "Personality and Proof: The Mind of Science" (1984/85). He states that the process of rationality involves value choices and personal biases toward evidence each step of the way. He stresses, moreover, that there can be no science without the scientist, for human activity constitutes most of what we call science. Knapp concludes

that the claims that scientists are dispassionate, objective, and free from their humanity are incomplete and naive, both scientifically and psychologically.

Paul Campbell likewise argues that objectivity in science is impossible. In "The Personae of Scientific Discourse" (1975), he points out that in claiming objectivity, science has attempted to deny the existence of a persona, implying that persona and objectivity are usually "mutually incompatible god-terms" (398). Yet this very objectivity is a stance, one that Campbell shows to be changing. He refers to Kuhn's study that identifies the persuasive and rhetorical process in science of accepting new paradigms. Furthermore, Campbell finds that in striving for objectivity, predictability, and control, scientists distort and devalue. Values and beliefs are inevitably a part of scientists' choices of paradigms. Campbell admonishes those who remove objects from values for clarity or neutrality. He demands that science take responsibility for its perceptions, feelings, and observations that cannot be value-free, for "to discourse is to act, and the very act implies an actor" (405).

The Rise of Popularized Science

A variety of factors have created a need in this century to accommodate scientific information to the general audience. This popularized science movement has also significantly contributed to the more

humanistic view of the scientist, for in writing to popular audiences, scientists often reveal a more personal perspective toward scientific information. Several researchers have attempted to account for the rise of popularized science in this century and to show how popularized scientific writers have begun to challenge the scientific tradition that removes scientists from their work and denies them a voice in reporting scientific information.

The general public's fascination with science is a relatively recent phenomenon. In "What's Fueling the Popular Science Explosion?" (1980), Issac Asimov highlights the introduction of the nuclear bomb during World War II as a turning point in the public view of science. At that time, science became a matter of life and death, a matter too important to be left to the isolated activities of scientists. This change in the public view of science has made people desperate to understand science and has thus spurred an increase in the popularization of science.

Other researchers attribute the rise of popularized science to people's natural curiosity and their desire for control of their world. In their introduction to Writing about Science (1979), Bowen and Mazzeo add that though some people simply read scientific literature for enjoyment, most believe that if they understand the world, they have a better chance of controlling it. These authors report that before World War II a split had developed between expert

and lay audiences because scientists wrote primarily to peers. Following World War II, science not only grew more complex but the reporting of science became unintelligible to ordinary people. Since this time, popularizers of science have attempted to make science approachable for lay people by humanizing science, by showing that behind every discovery is a human being who lives in the same world as the common man.

It is not only the complexity but also the inhumanness of science that popular audiences find repellant. In his article, "In Praise of Science Writers" (1986), Colin Tudge adds that inhumanness in science is also threatening and misleading, for science is an immensely human activity. He suggests that writers would do science a favor if they would let uncertainties come through. Science, thus, must become less pompous, and scientific writers must dedicate themselves to making science interesting and accessible.

Popularized science has thus become a significant medium for communicating the impact of science on man. In "Fifty Years after the Death of Flammarion, the Science Popularizer" (1976), Novozhilov and Richardson contend that no longer can science be regarded as an isolated activity that operates neutrally. Science bears human consequences, and scientific writers must take responsibility for how they shape the information they present to the public. Novozhilov and Richardson add that scientific writers cannot avoid joining value judgments to the interpretations they pass along.

How Current Theories Define Persona in Scientific Writing

The literature discussed confirms that as a result of the rhetorical nature of science and its diverse audience, the persona of science has inevitably changed. This changing view of the scientific persona has furthermore prompted a significant number of studies during the past twenty years on the persona of the scientific writer. While some of these studies focus directly on persona as the ethos or voice of the writer, others refer to persona indirectly by way of related terms, such as personality, subjectivity, and creativity. Because the study of persona in scientific writing is relatively new, much of the terminology is inconsistent, yet regardless of the terms used, these studies generally focus on persona as the attitude that the writer exhibits toward the subject and the reader. These studies challenge the view that scientific writing is totally objective and instead suggest that the writer must adapt his or her persona to the audience and subject.

Studies on Persona, Ethos, and Voice

One way of defining ethos is to distinguish the kinds of ethos found in scientific writing. Eve Walsh Stoddard discriminates between initial and derived ethos while

Dorothy Margaret Guinn distinguishes between negative and positive ethos. In "The Role of Ethos in the Theory of Technical Writing" (1984), Stoddard refers to derived ethos as the ethos acquired during the discourse act while initial ethos is the ethos that exists prior to communication. She points out that, although derived ethos is more important, most studies focus on initial ethos. She further asserts that scientific writing cannot be objective and recommends an amended model of scientific discourse that considers the writer's entire rhetorical situation and applies concepts of persona to scientific writing. The writer should, therefore, approach the reader not as an adversary, but as a partner in bridge building and establish common ground by revealing to the reader both initial and derived ethos.

With the assumption that the individual voice is inescapable, Dorothy Guinn uses examples of prose from medical journals to define both negative and positive ethos. Focusing on how lexical choices create ethos, she finds, in "Ethos in Technical Discourse" (1983), that a negative ethos promotes objectivity and anonymity and produces a colorless, bland writing, packed with empty verbs, passive voice, and nominalizations. Appropriate lexical and syntactic choices can, however, yield a trustworthy, knowledgeable writer who still maintains an often necessary anonymity. She uses Lewis Thomas as an example

of a writer who gains the respect and interest of his audience by balancing professional and personal perspectives.

Other researchers attempt to define the appropriate use of voice in scientific writing. Stephen Bernhardt notes, in "The Writer, the Reader and the Scientific Text" (1985), that the presence of an active writer in the natural sciences is not only more honest but also more efficient. Although many scientists cling to the assumption that scientific writing is impersonal, Bernhardt reports that more and more scientists have begun to view scientific writing as a persuasive endeavor, an act of imagination between rhetor and audience, rather than the presentation of cold facts. He further points out the following "linguistic forms" through which writers enter texts:

- acknowledging assistance
- referring to one's own previous research
- stating and justifying the hypothesis
- justifying methods chosen
- explaining adjustments or inability to interpret facts
- comparing present findings with previous studies
- discussing implications.

Bernhardt concludes that these personal intrusions appear most commonly at certain junctures where the argumentative nature of a report heightens. He adds that the use of personality in scientific texts is a matter of degree: some texts may be more impersonal than others, but all texts show evidence of some degree of interpersonal meaning.

Hence, all writers assume a role in their writing, a voice that defines their relationship to the subject and

reader. In Breathing Life into Medical Writing (1982), Anitra Sheen observes that medical writers often assume a stilted, professorial voice in an attempt to stifle their individual voice. Yet, as Sheen explains, this affected voice may not truly reflect the writer's sense of the subject. While scientific writing should not be too casual, it should emanate from the natural voice of the writer. Sheen adds that this voice is most often reflected in tone, through the use of words appropriate to the subject and consistent with the writer's attitude toward the subject. She concludes that using a formal voice creates a distance between writer and reader as well as subject and reader. Writers must, therefore, realize that the method by which and extent to which they indicate their presence in the text significantly influences how a reader perceives the information.

Studies on Personality, Subjectivity, and Creativity

As the authors of these preceding works discuss the impact of the writer's voice on the text, they imply that the writer's personality is inevitably a part of his or her writing. W. Earl Britton contends that the matter of concern, then, is how much personality is acceptable. He states in "Personality in Scientific Writing" (1973), that in the applied sciences, personality is acceptable because scientists write to consumers rather than for the record as

do pure scientists. A cautious use of metaphor, analogy, allusion, and simile can illuminate and stimulate thinking without compromising accuracy. Britton gives examples from medical and military prose that substantiate his position and indicate a gradual shift toward more personal writing when it is appropriate to the situation and the reader.

Merrill Whitburn also speaks strongly against an impartial, disinterested, objective approach to science that implies that humans are subordinate and frail. In "Personality in Scientific and Technical Writing" (1976), he finds that the use of colloquial words, occasional digressions, analogies, and metaphors can arouse interest and sharpen awareness for lay audiences. With his illustration of Fontenelle's use of personality, Whitburn clarifies the kinds of personality intrusions that work.

Rubens concentrates his study of personality in scientific writing on how the intrusion of personality forces writers to take responsibility for their prose. In "Reinventing the Wheel? Ethics for Technical Communicators" (1981), he notes that scientific writing has inherited the problems of the discipline it supports. By denying human intervention, science has attributed problems and mistakes to objects and mechanisms. Rubens challenges the detached scientific

voice that has become an escape for writers and an excuse to refuse responsibility for the part of them represented in their writing.

Two studies on personality in scientific writing reiterate that scientific writing inevitably carries a degree of subjectivity. Scott P. Sanders notes, in "Subjective Objectivity. . . What I'm Teaching Now" (1987), that the heightened interest in the subjectivity of readers has shifted the focus in scientific and technical writing from the objective, verifiable contents of documents to the contexts in which readers receive them. Sanders, then, describes communication in scientific documents as a process whereby writers invite readers to join them in consensual agreement.

M. Jimmie Killingsworth argues that the lack of subjectivity in scientific and technical writing leads to "thingishness," an object-oriented prose that is both unreadable and pretentious. In "Thingishness and Objectivity in Technical Style" (1987), he attributes thingishness to an overuse of noun strings, nominalizations, passives, indirectness, impersonality, and abstraction. Killingsworth's chief argument against the use of these stylistic techniques is that they do not accurately represent the action-filled world in which scientific writing occurs, a world in which accountability is essential and relatedness is inevitable. Killingsworth concludes that writers can be objective without being

thingish by omitting words and structures that carry judgments. Writers should realize that these stylistic elements do not guarantee objectivity, which is a matter of content and context as well as style.

Creativity in scientific writing seems to be a more popular topic than either personality or subjectivity, for both scientists and rhetoricians note the creative nature of science. In The Panda's Thumb (1980), scientist Stephen J. Gould illustrates creativity in scientific writing with the unusual analogies he draws between science and such subjects as Mickey Mouse, Colonel Sanders, and Biblical characters. In addition, his occasional digressions and references to himself reinforce his statement that "an understanding of cultural bias forces us to view science as an accessible, human activity, much like any form of creativity" (13).

Several researchers have identified similarities between the process of scientific discovery and the process of invention in writing. John Childs observes, in "Where Techne Meets Poesis: Some Semiotic Considerations in the Rhetoric of Technical Discourse" (1986), that literary and scientific discourse are difficult to distinguish. While science has traditionally emphasized the message more than style, scientists have found that their disregard of style often results in extreme impersonality and objectivity that impede comprehension. Childs then suggests that the control of a researcher over research parallels

the writer's manipulation of information. He concludes that science is not purely referential, although the message of scientific discourse is primary. Thus, scientific writing is subject to many of the same tools of rhetoric as literary discourse.

Jerome Bump and Steven Rothmel give more detailed accounts of how scientific writing parallels the creative processes of literary discourse. Bump, in "Metaphor, Creativity, and Technical Writing" (1985), and Rothmel, in "Technical and Creative Writing: Common Process, Common Goals" (1981), note that creativity is a significant ingredient in science; it is the very essence of scientific discovery. Bump gives examples of scientific writers who communicate discoveries with first-person, emotional prose conducive to metaphor and creativity. The discoveries of Smeaton, Kepler, Copernicus, and Newton show how metaphor and analogy discourage either/or thinking and instead lead to new connections. Used properly, metaphorical tools not only help scientific writers invent, integrate, and synthesize, but also help them to communicate discoveries more clearly.

Although scientists are often reluctant to use many of the figures of speech, they do often find that metaphors help make difficult concepts clear, especially for the lay audience. In "Parallels in Scientific and Literary Discourse: Stephen Jay Gould and the Science of Form" (1986), Debra Journet finds that scientific models and metaphors have cognitive power, for they are

ways of organizing and filtering information. Moreover, aesthetics plays a role in the cognitive process of arriving at theories, as seen in scientists' construction of models and choice of metaphor and imagery. By showing the importance of aesthetics and the cognitive use of metaphor in Stephen Gould's essays, Journet supports the theory that scientific writing is essentially a rhetorical enterprise. While Corbett agrees with Journet, in "A Rhetorician Looks at Technical Writing" (1981), he warns writers to be judicious with the use of tropes and schemes and challenges writers, above all, to honor the accuracy of their information.

Halloran and Bradford conclude that scientists reject the use of many schemes--parallelism, antithesis, and apposition--because they distract from scientists' emphasis on regularity, predictability, and readability. In "Figures of Speech in the Rhetoric of Science and Technology" (1984), Halloran and Bradford argue that this emphasis, used in excess, has a negative return. In prose that is too regular, readers lose their sense of what is important and get bored. Comprehensibility is a more appropriate goal than readability, for comprehension is more a product of syntax, style, cadence, and structure than the result of simple, readable words and sentences.

Literary and scientific writing share other similarities in addition to their metaphorical nature. In "Readability and Creativity in Technical Writing" (1980),

Bert Edens suggests that conciseness, word choice, and logical structure require creativity from the scientific and literary writer. Focusing on the concern in scientific writing for readability, he asserts that "writing is only readable when it is creative" (329). In "Poetry, Imagination, and Technical Writing" (1985), Russell Rutter points out that poetry and scientific writing both rely on intuition, imagination, selection, and shaping. He adds that while scientists deify fact and deny any imaginative influence on their writing, current scholarship suggests that science is imaginative because it focuses on a mental process that relates thought to object. This mental process, like poetry, shapes disparate facts into meaningful communication of truths.

These numerous studies on the similarities between rhetoric and science and between creativity and scientific discourse confirm that science and scientific writing are creative activities. In "Defensive Aesthetics for the Technical Writer" (1982), Marder and Guinn argue for the use of creativity and aesthetics in scientific writing. They do not propose flowery language; in fact, they find that the "machinelike encodings" of the usual technical and scientific documents are more "ornamental than any produced by a writer sensible of aesthetics" (36). When writers experience tension between an accurate and graceful statement, accuracy wins because grace is not valued in the utilitarian environments of science and technology. By

proposing a balance, "a playful jousting," between accuracy and aesthetics, Marder and Guinn refute the stereotypical antithesis of these equally valuable characteristics.

How Persona Enters Scientific and Popularized Texts

Recent theories of persona verify that scientists inevitably communicate a persona in their writing, whether this persona be that of an impersonal, detached scientist or that of a personal, involved human being. Furthermore, the particular ways in which scientists treat such conventions of scientific writing as content, organization, and style contribute significantly to the kind of persona they create. Thus, to lay the groundwork for determining how Thomas creates his persona in The Lives of a Cell, I discuss ways in which both scientific writers and popularizers of science create persona through content, organization, and style.

Content of Scientific and Popularized Writing

The particular subjects of scientific discourse are not as important to creating persona as scientific writers' approaches to these subjects. Scientific writers are primarily concerned with the things, objects, and realities of science. As Kinneavy confirms in A Theory of Discourse (1971), scientific writers focus on a facet of an object and make only referential assertions about this object (88).

Robert Day points out that the goal of scientific writing is to reproduce experiments so that others may assess, repeat, and evaluate scientists' work (2). As writers focus on the object or reference, they exclude their personal feelings and disregard the reader as a target of emotion (Kinneavy 88). This thing-oriented approach to the subjects of science distances the writer from both text and readers and thus contributes to an impersonal, detached persona. Scientific writers eschew humor and are careful not to allow things to perform human actions.

While the subjects of popularized scientific writing may not differ significantly from scientific writing, the degree of emphasis on reality and the approach to scientific subjects differ greatly. Popularized scientific writing is grounded in the facts and accepted notions of the scientific discipline it supports (Kinneavy 102). Yet the purpose of popularized science is to humanize science for lay audiences (Bowen and Mazzeo 4); therefore, popularizers find that to humanize science, they must assume a more personal, humanistic approach to science. Popularizers are not interested in reproducing experiments so that they may be repeated, assessed, and evaluated. Therefore, popularized scientific writing may be, on one hand, more pragmatic, bringing science into the sphere of everyday experience. To bridge the gap between science and everyday experience, popularizers must show readers the human behind scientific facts (Bowen and Mazzeo 4).

Popularizers also give more background information and use more analogies and examples to put science in the context of everyday experience (Killingsworth, "Science" 186). They are often more philosophical, exploring the truths of scientific beliefs. These writers give the impression of personal exploring in their writing as in the case of Lewis Thomas who often shows the process of how he arrives at an idea (Dowdy 5). By offering numerous examples and injecting personal references, the writer mitigates the view of the depersonalized scientific writer and instead creates the image of a person behind the text, one who focuses on the doer and receiver of scientific fact rather than solely on scientific objects.

Organization of Scientific and Popularized Writing

Scientific writers demand a conformity in organization that discourages individualization and thus contributes to a detached persona. Much of scientific writing is organized according to either deductive or inductive patterns. In deductive organizational patterns, the writer initially sets up a theorem of propositional logic and then draws inferences from it (Kinneavy 153). In this process, the writer often uses induction to assert or negate the premises. Inductive organization may also be used if the writer wishes to move from particulars to concluding generalizations (153).

In addition to these logical patterns that serve as organizational patterns for scientific writing, there are conventional patterns of organization that many writers follow. These patterns reflect the scientific method of investigation[3] and consist of the following:

-an introduction that defines the problem

-the materials and methods sections that tell how the scientist conducted the study

-the results that tell what the scientist found and

-the discussion that tells what the results mean (Day 23-33).

Lipson adds that these organizational conventions reinforce the primacy of objects, the primacy of the facts of nature (13). Scientists are "disempowered" (13); they are not in control but are, instead, testers, or observers, collectors of facts who put these facts into pre-established organizational forms that allow little room for individual preferences or shaping.

The organizational pattern of popularized scientific writing is much less prescribed and, therefore, allows more opportunity for personal intervention. Because popularized scientific writing is often exploratory and philosophical, there is no particular form into which such kinds of inquiry fit. Kinneavy observes that exploratory discourse of this kind does not often display the precise formulations that scientific discourse exhibits (162). The most common forms in which popularized science is found are

the journal article and the essay. Killingsworth adds that the personal essay is particularly suited to popularized science because it is an organic form; its structure thus emerges from conception in thought, feeling, and personality of the writer ("Science" 187) rather than from some pre-established form. Kinneavy identifies the Socratic dialectic as the pattern of many popularized science essays. The introduction sets up the narrative component. The spirit of intelligent curiosity is established; then, the writer divides the topic and proceeds to the hypothesis which is inductively tested and evaluated (Kinneavy 165). Therefore, most popularizers of science do not follow the formulations of scientific discourse, but instead allow their organization to follow their own thought processes. By allowing readers to observe their thought processes through the organization of their writing, popularizers become individuals to their readers, persons with specific preferences and personalities.

Style of Scientific Writing

Style reflects more clearly than do content and organization how scientific writers and popularizers of science create persona. Furthermore, more researchers have studied scientific style than other elements of scientific writing. Croll, Jones, and Williamson offer significant studies on the seventeenth-century Attic and Ciceronian influences on the scientific prose style of today. They

discuss several factors[4] that influenced the rise of the plain prose style, one of the most significant being the new science, advocated by Bacon and the fellows of the Royal Society, that gave more outward confirmation and credibility to this prose style. Moreover, Sprat's History of the Royal Society (1667), the first significant record of this plain style prose, advocates a style that accurately and briefly reports on the things of science rather than on the persons performing experiments:

> There is one more thing about which the Society has been most solicitous; and that is the manner of their Discourse:. . . And in few words, I dare say that of all the Studies of men, nothing may be sooner obtained than this vicious abundance of Phrase, this trick of metaphors, this volubility of Tongue, which makes so great a noise in the World. . . . It will suffice my present purpose to point out what has been done by the Royal Society towards the correcting of excesses in Natural Philosophy to which it is of all others, a most profest enemy. They have therefore been most rigourous in putting into execution the only Remedy that can be found for this extravagance, and that has been a consistent Resolution to reject all amplification, digressions, and swellings of style, to return back to the primitive purity and shortness, when men

> delivered so many _things_ almost in an equal number of _words_. They have exacted from all their members a clear, naked, natural way of speaking, positive expressions, clear senses, a native easiness, bringing all things as near the mathematical _plainness_ as they can, and preferring the language of Artizans, Countrymen, and Merchants, before that of Wits and Scholars. (112-13)

While there have been some modifications in style since the time of Sprat, "the main prescriptions in English had been consciously written by the mid-seventeenth century" (Kinneavy 170). Scientists today still strive for a clear, concise, and precise style with which they can report the things of science without the intrusion of their own voice. Many scientists describe the appropriate style for scientific writing as unobtrusive, an invisible medium through which readers may clearly view the objects of science (Miller 612). The goal of this unobtrusive writer is objectivity, "the great virtue of scientific style" (Kinneavy 174). Although writers have begun to realize that complete objectivity is theoretically impossible, it remains the ideal for scientists who desire to reproduce reality as accurately as possible and provides the stimulus for many of the semantic and grammatical characteristics of scientific style. In scientific writing, the use of nominalizations, expletives, and

passive voice, in addition to the paucity of figurative language and humor, stem from the writer's desire to avoid personal intrusions and thus create an objective persona.

Word Choice. The diction of scientific writing emphasizes the things of science with its dominance of nouns, jargon, Latinate words, and multiple adjectives and paucity of action verbs and figurative language that suggest the persons performing scientific acts. Many of the nouns used in scientific writing are abstract words, for many of the realities that science refers to are abstract. While scientists may attempt to illustrate abstractions with concrete instances, they often find that illustrating abstractions obscures the meaning (Kinneavy 177).

Another tendency of scientific writing that contributes to the dominance of nouns and the emphasis on the things of science is the use of nominalizations and nouns strings. Scientific writers form nominalizations by converting verbs to nouns as in the following sentence: "Measurement of the internal diameter was performed by the scientist." By using the noun measurement instead of the verb measure, the writer emphasizes the product of the action rather than the doer of the action. A more direct and concise statement would be "The scientist measured the internal diameter." Scientific writers also tend to use noun strings, or a series of nouns used to modify another noun, as illustrated in the following phrase: "pressure heat capacity temperature maxima"

(American National 12). Again, the desire for accuracy and conciseness in representing reality is often the reason for using nouns strings, but in doing do, writers now find that they often reduce the readability of such phrases.

Lipson attributes the heavy reliance on nouns in scientific writing to the primacy of objects and facts in science (13). Schindler adds that the facts of testing have always been regarded as more significant in science than the act of testing. He also finds that nouns more appropriately represent the measurements, designations, and dimensions upon which science is based (6).

Jargon and Latinate words are other noticeable characteristics that contribute to the formality, complexity and inhumanness of scientific writing. Kinneavy, as do Brusaw, and Turk and Kirkman, defines jargon as the dialect of a particular discipline.[5] These researchers find that jargon is necessary for reporting complex information with accuracy. Kinneavy observes that jargon, unlike gibberish and gobbledygook, almost always is the result of the author's good intentions--to be accurate and precise (176). McAllister encourages scientists to use jargon, but to define terms the first time they use them and to write different versions of definitions to meet the needs of multiple audiences (531). Jargon is, therefore, desirable when it serves as a vehicle for the accurate, efficient communication between experts,

but inevitably increases the formality of scientific writing and thus alienates expert scientific writers from people outside their area of expertise.

As in the case of jargon, Latinate terms are often used for accuracy, especially where Anglo-Saxon offers no exact synonym. The medical and biological fields particularly follow the tradition of using many Latinate words (Baker, John R. 851). Yet Latinate words also increase the formality and consequently the objectivity of scientific writing. Many people interpret the excessive use of Latinate terms as the writer's effort to impress readers, for a Latin vocabulary has, since the Middle ages, been a mark of the educated (Turk and Kirkman 111). Thus, writers using a significant number of Latinate words add to the complexity of their writing and communicate a detached, often pedantic persona.

The use of figurative language in scientific writing has been debated since Sprat described scientific style in his seventeenth-century History of the Royal Society, for it adds an element of subjectivity and personality that scientific writers avoid. However, some scientists have found that metaphors are so useful in scientific writing that they more than compensate for the loss of objectivity. For instance, Bump records that the discoveries of Smeaton, Kepler, Copernicus, and Newton show how metaphor and analogy discourage either/or thinking and instead lead to new connections (445). Anitra Sheen encourages scientific

writers to use figurative language with restraint, discretion, and logic (95). She asserts that metaphors are not just stylistic ornaments, but are means by which people come to know something, for metaphors tap powers of association in all audiences. Sheen adds that metaphors can be plain, making a direct comparison (He is a rock); implied, requiring two or more associative steps to make the comparison (She buttressed our spirits); or extended, sustaining the comparison through a series of terms (97-98). Similarly, these scientific writers communicate their personality with their particular choice of analogies used to express the unfamiliar in terms of the familiar.

Syntax. Scientists communicate objectivity through syntax by relying heavily on declarative sentences and avoiding the more emotional exclamatory and imperative sentences (Kinneavy 178). Although scientific writers predominantly use normal word order rather than periodic and inverted syntax, they add to the complexity of their writing and the formality of their persona by writing abnormally long sentences. Scientists characteristically write long sentences because they want to complete an idea and represent it correctly by including all of the necessary qualifiers in one sentence (Schindler 6-7). As a result, scientific writers tend to use many subordinate clauses and multiple adjectives to qualify their ideas, increasing the distance between reader and writer and creating a persona of the detached writer.

Passive Voice. The tradition of using the passive voice in scientific writing stems largely from the scientist's desire for objectivity.[7] Scientific writers have long attempted to focus on the objects of science rather than on the doers of action. Schindler adds that scientists use passive voice to avoid pompous personal references like " I designed. . . ." Hence, scientific writers characteristically write "the compounds were separated," focusing on the object by placing it first and by omitting the agent, or doer of the action. Yet research in cognitive psychology has brought the use of passive voice into question. Kintsch documents that passive voice takes longer for readers to process (303). Researchers on writing find that the excessive use of passive voice has negative effects, for the passive reverses the normal subject-verb-object word order of a sentence. In addition, readers find it easier to focus on the agent of the action first (Turk and Kirkman 119). Writing researchers now encourage scientific writers to use passives only when they have a "specific encoding function" (Turk and Kirkman 120) as in a situation where the agent is unknown or the writer wishes to conceal the agent. Moreover, Flower, Hayes, and Swarts have found that readers respond more positively to actions placed in the active voice with persons performing the action (56). These researchers confirm that passive constructions not only add to the complexity and length of sentences, but also make them impersonal.

Style--Popularized Scientific Writing

The most noticeable distinction between the style of scientific writing and the style of popularized scientific writing is the increased presence of the writer's personality in popularized scientific writing. To increase a general audience's interest and understanding of scientific subjects, scientific writers attempt to humanize science. They use a human voice that speaks of human experience to a human audience, for the non-human, mechanical writing that is appropriate for colleagues appears cold to lay audiences (Killingsworth, "Science" 186). Simplifying scientific material is not enough for popularized scientific writing. Writers find that for general audiences, they must put scientific subjects in the context of persons, rather than things. Hence, writers often use biography or autobiography to add a human element that allows them to inject scientific material (Dowdy 5). Writers, like Lewis Thomas, give readers the process by which they arrived at an idea (5). They frequently use personal pronouns, referring to the author as I, the reader as you, and to both author and reader as we. The general personalism of popularized science, furthermore, significantly affects the other elements of style--word choice, syntax, and the use of passive voice.

Word Choice. Because popularizers of science seek to humanize science for lay readers, their diction differs

significantly from the diction of scientific writing. In general, the diction of popularized scientific writing is less formal than that of scientific writing. Popularizers often use contractions and idiomatic expressions, giving their prose a more conversational style and creating a persona of the ordinary human being. Popularizers also avoid jargon, introduce new terms gradually, and use short words where possible (Gastel 8-9), to reinforce this persona. Popularizers freely use figurative language, such as analogy, simile, metaphor, personification, synecdoche, and allusions which help to portray the particular personality of the writer. Also, figurative language is effective in popularized scientific writing for adding concreteness, demonstrating ideas, and stimulating interest. In addition, popularizers also communicate personality through word play and humor which make their scientific prose less threatening (Dowdy 10).

Syntax and Passive Voice. Few researchers have analyzed the syntax of popularized scientific writing. Gastel finds that the normal word order and shorter sentences of popularized scientific writing contribute to a more personal, conversational style than that of scientific writing (9). Moreover, I have observed in the popularized writing of Gould and Thomas that they do not rely only on declarative sentences, but also write exclamatory sentences and sentence fragments which more closely reflect casual speech. Also the more frequent use of personal pronouns

in popularized scientific writing reduces the number of passive voice statements and gives writers the opportunity to add a human element with human agents who perform the actions of the sentence. Hence, the short, conversational style sentences with human agents communicate a writer willing to share his or her more human voice with the audience.

This chapter reviews a significant amount of scholarship that challenges the traditional view of scientific writing as totally objective and argues that scientists and popularizers alike inevitably communicate a persona. Many of these researchers identify similarities between science and the more subjective, creative elements of writing. Their focus is, therefore, on the appropriate use of this subjectivity and persona in scientific writing. They do not suggest that total subjectivity and creativity replace objectivity in scientific writing, but recommend that writers adapt their persona to their audience and purpose. Lewis Thomas offers a good example of a scientist who has appropriately adapted his persona in The Lives of a Cell to his lay audience, for he communicates a personalism in his writing that interests his audience, without compromising his professional voice. As I show in the next chapters, through his organization, content, and style of The Lives of a Cell, Thomas creates the persona of a man who is eager to

share his enthusiasm for scientific subjects with his audience.

Notes

[1] Though my focus in this paper is popularized scientific writing, I include in this literature review those studies of persona in scientific writing for experts because few studies distinguish between the two kinds of writing. Furthermore, developments in scientific writing for experts inevitably affect all of scientific writing, even writing to popular audiences.

[2] Paul Feyerabend, born in Vienna, Austria in 1924, is a philosopher, educator, and author. He has held professorships in philosophy at the University of California at Berkeley, at the Free University of Berlin, and at Yale University. He was also professor of philosophy and science at the Federal Institute of Technology in Zurich, Switzerland. His area of interest is the history of science and the history of ideas. He wrote Science in a Free Society in 1978 and has written numerous articles in philosophy, theatre, and physics ("Feyerabend, Paul K.," Who's Who).

[3] W. Paul Jones identifies the steps in the scientific method as follows:

-defining the problem
-summarizing work already done
-comparing similar phenomena
-forming a hypothesis
-extending or modifying the hypothesis
-testing the extended or modified hypothesis
-publishing the results
-submitting the final hypothesis for verification, and
-establishing a theory (21-23).

[4] Morris Croll, Richard F. Jones, and George Williamson discuss several factors influencing plain style prose in the seventeenth century. Among the major influences were rationalism, science, the rebirth of classicism, utilitarianism, the rise of the middle class, and the printing revolution.

[5] Although I use Kinneavy's positive definition of jargon, I also acknowledge that other scientific writers (such as Robert Day) refer to jargon negatively as the excessive use of technical or scientific terms.

[6] The periodic sentence was characteristic of the Ciceronian style and is a sentence that delays its main idea until the end of the sentence, presenting the subordinate ideas and modifiers first.

[7] Turk and Kirkman record that the average number of passive constructions used in novels is 6% while the total in one study of scientific writing was 32% (119).

CHAPTER III

ORGANIZATION COMMUNICATES PERSONA

Thomas states that the aim of his popularized writing is to reveal and change the public's misconceptions about scientists (Dowdy 15). He adds, "I want people to know that it's great fun to look at it [nature]" (15). One misconception that Thomas alters significantly through the persona he communicates in his popularized writing is the the stereotyped view of the detached, unemotional scientist. He communicates this persona by using the more individualistic form of the informal essay which by its nature allows more opportunity for personal intervention and intimacy with the audience. Thomas admits his own particular preference for the essay form that offers a freedom in the composing process and an outlet for his self-expression. Hence, as the organic nature of his organization indicates, Thomas composed these essays "as ideas popped into my head, mostly on the weekends and late at night. There was a certain amount of leisure involved" (Thomas, Interview). The structure of Thomas' essays, therefore, emerges from his thoughts, feelings, and personality. Organizing his essays largely by his own processes of discovery, Thomas communicates an openness to his audience, allowing them to see the unguarded processes of his

thoughts and feelings. With this method of organization he, moreover, connects with his audience, for his focus is not on presenting them with organized answers but on suggesting, instead, "let's explore the possibilities together."

Thus, there is no one characteristic method of organization for Thomas' essays. However, in the chapter that follows, I focus on the two very general types of organization that he uses most often, to show how each communicates an aspect of Thomas' persona: the organic and straw man methods of organization.

Organic Organization

Because Thomas' essays are exploratory, theoretical, and philosophical in nature, they all may be characterized, in one sense, as organic, following the processes of Thomas' mind as he deals with the issues raised by scientific subjects. Very often this process does not bring Thomas to a clear solution or conclusion; however, concluding does not seem to be his intent. With the somewhat loosely organized essays that, like his insects, often dart from premise to premise, he creates a mood of questioning and communicates the persona of one who values intelligent curiosity. With this kind of organization, he stimulates his audience to likewise let their minds carry them where they will on topics such as our affinity to insects, our difficulty with death, our need for myths, and the interconnectedness of all parts of the universe. A Thomas essay that follows the organic

method typically moves in the following manner:

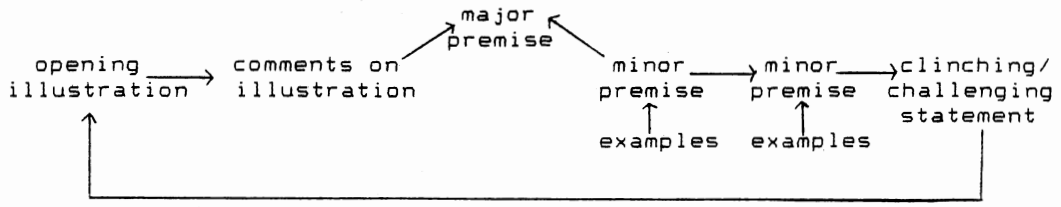

Figure 1. Diagram of Thomas' Organic Organization.

In essays organized by this organic method, Thomas generally moves from an opening illustration (usually an instance from human experience or science) to following paragraphs that comment on the illustration. Often Thomas discusses the illustration for several paragraphs before he states his major premise which gives relevance to the opening illustration. After stating his premise, he explores different avenues suggested by this topic, often finding a related premise that takes him to other premises in a kind of domino effect. With each premise, he characteristically gives several examples to illustrate his meaning, and often toward the end of his essay, in his final example or conclusion, he returns to the subject of the opening illustration, giving the essay a sense of completion. However, in the endings of his essays, he seldom gives definitive conclusions or summaries, but more often continues the exploratory nature of his essay by ending with an admonition that incites further action or a

clinching statement that stimulates further thought. The following outline illustrates this organic pattern in the essay "On Societies as Organisms."

Opening illustration: Description of physicians at medical meeting in Atlantic City

Major Premise: Humans sharing information resemble insects at a distance.

Examples

1. Ants
2. Termites
3. Bees
4. Slime mold
5. Herring

Minor Premise: Humans do not feel conjoined intelligence as do insects.

Example: Computers

Minor Premise: The system of communication in science is a model for studying information-building in human society.

Example: Ziman's article in Nature

Clinching Statement: "We like to think of exploring in science as a lonely, meditative business, and so it is in the first stages, but always, sooner, or later, before the enterprise reaches completion, as we explore, we call to each other, communicate, publish, send letters to the editor, present papers, cry out on finding." (16)

Figure 2. Organic Organization in "On Societies as Organisms."

While "On Societies as Organisms" offers a good example of Thomas' organic organization, it also demonstrates that none of his essays follows every aspect of a particular pattern. Hence, unlike this essay, Thomas usually delays the statement of his major premise until several paragraphs into the essay, after discussion of the opening illustration. In this essay, he states the major premise in the second paragraph, immediately following the opening illustration. By delaying the statement of his major premise, Thomas instills a feeling of uncertainty that incites the reader to read on to discover how the illustration relates to the topic stated in the title. However, Thomas is consistent, in this essay and all others, in his use of examples to illustrate each premise. Often one of these examples carries him to another point that in turn may lead to another. While some of these points support the major premise (as in the case of the sub-premise in "On Societies as Organisms"), others may carry the discussion in a different, often remotely related, direction from the major premise, as in the case of the minor premise in "On Societies as Organisms." Between his final example and the conclusion, Thomas offers no transition, but returns to the subject of the opening illustration, thus giving a very general sense of cohesion to the organic structure of his essay.

Thomas communicates valuable information about himself through the organic organization of his essays. Ironically, through this kind of organization, Thomas expresses that he is in control of the essays' organization. Because he does not use some pre-established form of organization, he controls the direction the essays will take. Lipson adds that scientists who follow conventional patterns of organization are "disempowered" (13). They are not in control but are testers, observers, collectors of facts that they put into pre-established forms (13). Moreover, Thomas suggests through this method of organization that he values the unpredictable. No doubt a writer of his expertise could easily put his thoughts into patterns of organization that his audience would readily recognize and feel comfortable with. However, by organizing primarily according to his own train of thought, he stimulates the audience's curiosity; he further implies that uncertainty creates the thirst for knowledge necessary for discovery.

The Straw Man Organization

The straw man method of organization, or setting up an argument against the writer's point and then disproving that argument, is the most identifiable kind of organization used by Thomas in <u>The Lives of a Cell.</u> Through this method of organization, Thomas communicates the persona of the iconoclast, a man who

enjoys unsettling given, unquestioned notions, and destroying common misconceptions. I have identified thirteen of his 29 essays in The Lives of a Cell that follow the straw man form of organization:

- "The Lives of a Cell"
- "Thoughts for a Countdown"
- "The Music of This Sphere"
- "The Long Habit"
- "Autonomy"
- "Organelles as Organisms"
- "Germs"
- "Your Very Good Health"
- "Death in the Open"
- "The Iks"
- "Computers"
- "Some Biomythology"
- "On Probability and Possibility."

With his choice of subjects for this straw man kind of organization, Thomas shows his awareness of the human misconceptions that merit refutation, for he deals with such commonly-held misconceptions as the exclusiveness of the human species, the isolation of people from nature, the fear of death, the superiority of computers, and the resistance of mythology. He also communicates, through this organization, that disagreement enlivens discussion.

A typical essay organized according to the straw man principle will begin with an argument, opinion, or belief that Thomas then refutes. Barbara Lounsberry notes that Thomas typically begins by articulating a traditionally held notion only to "quickly ambush it, hold it up, like a wriggling laboratory specimen to scrutiny" (8). Thus, he devotes the remaining part of the essay to his counter-argument, although he does characteristically state and resolve some of the opposition's concerns. The organization of his argument fits no particular pattern; he simply moves from supporting argument and examples to other supporting arguments and examples. Likewise, his ending varies from the clinching statement to the statement of challenge. The diagram on the following page illustrates how Thomas develops his straw man organization.

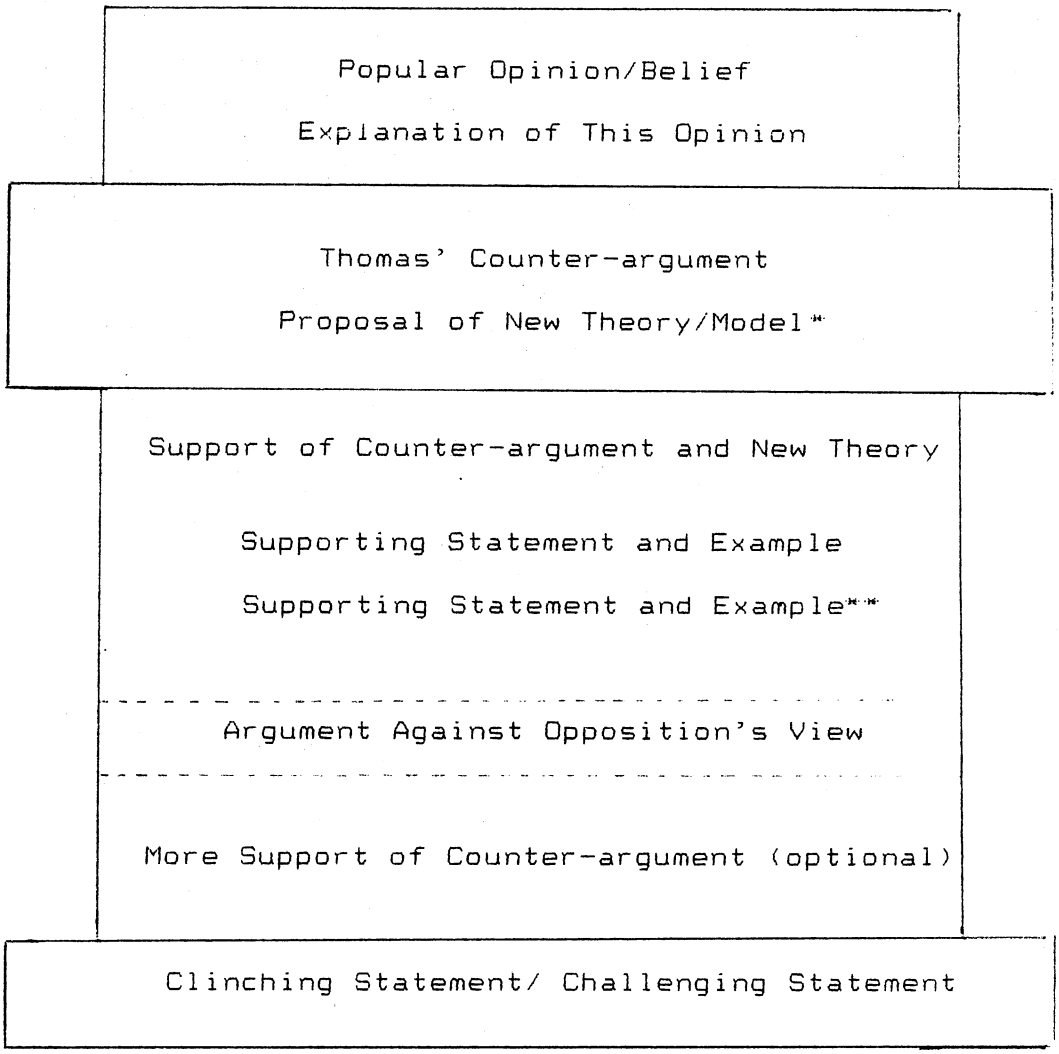

Figure 3. Diagram of Straw Man Organization in Thomas' The Lives of a Cell

*The placement of the new theory varies from essay to essay.
**The number of examples varies in each essay.

The outline of the essay "Germs" on the following page further illustrates how this method of organization operates in a Thomas essay.

Popular Belief: "You'd think we lived. . . in total jeopardy, surrounded on all sides by human-seeking germs" (88).

Explanation of Belief: Humans are instructed to spray disinfectants everywhere, explode clouds of aerosol, apply potent antibiotics to scratches, and wrap everything in plastic for protection.

Counter-argument: These are paranoid delusions, explained by the human need for enemies, and the memory of the way things used to be. Germs are not as harmful as we think.

New Theory: Disease usually results from "inclusive negotiations for symbiosis. . . an overstepping of the line by one side or the other. . . " (89).

Support of New Theory and Counter-argument:

Some bacteria only harm humans when the bacteria make exotoxins, and they only do this when they are diseased themselves.

Examples: diphtheria bacilli and streptococci

Germs gain little by the capacity to cause illness.

Example: meningococcus

Staphylococci and humans have a congenial relationship.

Example: Hemolytic streptococci and humans share antigens.

Most bacteria are preoccupied with only browsing.

Example: Bacteria used in plants for energy
Bacteria part of nutritional system in insects

Address of Opposition's View: The microorganisms that harm us do so because of our response to them; our defense mechanisms cause more harm than do invaders.

Example: Gram-negative bacteria are read by cells as bad.

Clinching Statement: Mechanisms used for overkill are sometimes immunologic but are often more primitive kinds of memory. "We are, in effect, at the mercy of our own Pentagons" (94).

Figure 4: Outline of Straw Man Organization in "Germs."

In this essay, as in his other "straw man" essays, Thomas states the opening argument without letting the reader know, initially, that he opposes it; he initially identifies with this view: "We still think of human disease as the work of an organized, modernized kind of demonology. . . . We assume that they somehow relish what they do" (88-89). By stating an opposing view in this way, Thomas avoids the tendency in this kind of organization to become contentious and thus alienate his audience. He eases the audience into his counter-argument by first placing himself among those humans who hold a traditional belief that, because of the changing times, he now sees as incorrect. With this gradual working into his counter-argument, Thomas maintains his persona of the involved scientist but adds also the persona of the iconoclast who encourages his audience to question given notions and seek better solutions. Hence, in "Germs" he logically, and somewhat humorously, rather than condescendingly or viciously, accounts for the opposition's belief about germs: memories of the past and the human need for enemies account for the fear of germs.

After stating his counter-argument, that the human fear of germs is a delusion, Thomas proposes a new theory: that when germs or humans overstep their roles, disease occurs. He follows with examples that explain how germs generally intend no harm but that humans often cause disease by their overreactive response at the sight of a germ. Thomas also addresses some of the oppositions's

complaints with his position and proves these complaints to be unfounded. Furthermore, his ending in this essay is appropriate for a straw man organization, for he reiterates his position with a clinching statement that again identifies humans' contributions to disease: their over-reactive defense mechanisms, or "Pentagons" (94). This ending is helpful for restating his position, after having argued both sides on this issue of germs.

In both the organic and the straw man kinds of organization, Thomas communicates a control over the ordering of his text. Thus, with the organic organization, he follows the processes of his mind rather than the prescribed forms of scientific discourse. With the straw man organization, he maintains control, for in discussing opposing ideas, he focuses on the strengths of his own position rather than attacks those who believe differently. With the organic organization, he also communicates the value of uncertainty for stimulating discovery, while with the straw man organization he suggests that he values healthy argument for stimulating thought.

However, the most significant effect these kinds of organization have on Thomas' persona is their communication of his connectedness to his audience. With his organic organization, he creates an intimacy with his audience as he shows them the processes of his mind, revealing his thoughts much as one would when having a conversation with a friend. He thus identifies with his audience whose intelligent

ramblings likewise comprise the majority of their daily thought processes. Furthermore, with the straw man organization, he argues generally accepted notions that individuals have likely disagreed with secretly for some time. Hence, his organization, like his content, is significant for creating the persona of the involved scientist who prefers the cliche "we for one" to the less complimentary "I for one" (106).

CHAPTER IV

CONTENT COMMUNICATES PERSONA

Content, like organization, is significantly influenced by Thomas' use of the informal essay in The Lives of a Cell. The essay gives the writer more freedom to explore aspects of human experience which may be outside the immediate focus of the essay but which broaden the appeal of the subject matter (Killingsworth, "Science" 187). The essay also allows for a variety of rhetorical techniques that add a general personalism to the text (187). Hence, Thomas does not confine his content to scientific subjects, but uses them as springboards for exploring other philosophical topics common to human experience. Through the use of such rhetorical techniques as questioning, discovery, opinion, personification, example, humor, and emotion,[1] he presents the content of his essays and reveals himself as the physician who values exploration and the man who is supremely interested in humankind.

Thomas' Appreciation for Exploratory Science

In The Lives of a Cell, Thomas establishes a different approach to scientific subjects than one characteristically finds in scientific discourse. To use

Kinneavy's terminology, Thomas' approach to his subjects is more exploratory than scientific, more person-oriented than thing-oriented (Kinneavy 88). Though both exploratory and scientific discourse are concerned primarily with the physical reality to which discourse refers, exploratory stimulates questions and encourages discovery and opinion while scientific discourse seeks not only to give answers, but to prove them correct (89). Because of the nature of exploratory discourse, the encoder and decoder enter the text more frequently than they do in scientific texts that allow no intrusion of the author.

According to Kinneavy's description, Thomas' essays would be considered exploratory for, while science is the topic of the majority of Thomas' essays in The Lives of a Cell, he characteristically uses these topics as springboards for discussing the philosophical issues that scientific activity raises. (See TABLE I on pages 89-92 for an account of the issues discussed in each of Thomas' essays.) As this table shows, the main philosophical issue that recurs throughout The Lives of a Cell is the interconnectedness of all living things, the symbiotic nature of life. With this topic, in the first essay of his book and in the majority of other essays, Thomas dispels the possibility that he or any other human being can be

detached from the rest of humankind. He opens his book with, "We are told that the trouble with Modern Man is that he has been trying to detach himself from nature"(1). In his next chapter, he further connects with the human being reading his text by stating, "We do not have solitary beings. Every creature is, in some sense, connected to and dependent on the rest" (6). He works this theme into many of his other essays on scientific topics such as interstellar communication, computers, and scientific research. He demonstrates his own connectedness to his audience by speaking to them as one part of the "grand canonical ensemble" (28) of life.

Also instigated by scientific topics are other philosophical topics which illustrate Thomas' concern with the effect science has on people. In "The Iks," he opens with a description of nomadic hunters of northern Uganda, the Iks, in order to illustrate how men like the Iks have not learned to live together. He uses the topic of interstellar communication in "Ceti" (the name of a nearby star) to explore the possibility that our ability to communicate with other planets has diminished our view of earth; "it has lost its look of immensity" (50). The Marine Biological Laboratory serves as a model for social interaction in "The MBL" as Thomas explores the effects of man's

being a social species. Likewise, in "Computers," Thomas opens with a description of the human qualities of computers, then isolates the characteristic that prevents computers from becoming fully human, the capacity for collective behavior. In these essays, therefore, Thomas speaks knowledgably of science but applies science to issues that concern all human beings. With this emphasis he communicates the persona of one whose interest extends beyond scientific research to concern for how research affects people's lives.

Thomas further develops these exploratory subjects, not by the testing or experimentation characteristic of scientific discourse,[9] but by such techniques as questioning, discovery, and opinion. Thomas thus communicates the persona of one who is open to question, who appreciates the process of discovery, and who values personal opinion.

Questioning.

Thomas' use of questions indicates his interest in pursuing numerous possibilities rather than always seeking for convenient answers. By posing questions to his audience, he stimulates their thinking and involves them in the all-important search for answers. While questioning seldom yields the answers and proof desired by traditional scientific discourse, it is nonetheless essential to the scientific process. According to Kinneavy, "to limit reference discourse to propositions which can be

either empirically or logically proven true or false is to rule out much that is useful in exploratory and scientific discourse" (76). Thus discussing death in "The Long Habit," Thomas concludes that dying is "a coordinated, integrated physiologic process in its initial, local stages" but is unable to account for the "permanent vanishing of consciousness" (60). He asks, "Are we to be stuck forever with this problem? Where on earth does it go? Is it simply stopped dead in its tracks, lost in humus, wasted?" (60-61). He has no "data on the matter" and can only offer his opinion as a response, thus leaving the issue open for the audience to consider further.

In exploring the nature of interstellar communication in "Ceti," Thomas, assuming that man is able to get in touch with life on other planets, questions the reader and himself: "What on earth are we going to talk about?" (52). He gives the reader more specific topics to think about by suggesting some questions we might ask when communicating with life on other planets: "What are your smallest particles? Did you think yourselves unique? Do you have colds? Have you anything quicker than light?" (53). Yet Thomas concludes that the main question is the opener, "Are you there?" and suggests that before asking that question we must be prepared for the possible response "Yes, hello" (54).

By using questions such as these, Thomas expresses his desire to join the reader in exploring hard-to-answer

subjects, communicating the persona of a man involved in the same human endeavors as his audience.

Discovery.

Thomas suggests that the process of discovery is as important as the discoveries themselves as he communicates in many of his essays the process by which he arrives at an idea. (See TABLE I on pages 89-92 for a complete account of the essays that Thomas develops by discovery.) Also, by letting his audience see this process, he humanizes his essays as he communicates his own uncertainties and problems encountered during the discovery process. One of the main processes by which Thomas discovers his thesis is by stating an accepted belief that he argues against, giving examples that call into question the features of the accepted belief, and then proposing a new theory or model. Often his choice of a new model is unconventional, communicating an image of the non-conformist. His essay "The Music of This Sphere" offers a good example of how Thomas communicates this process of discovery.

Thomas demonstrates the value of healthy argument in this essay as he shows his audience how he came to disagree with the commonly-held belief that the sounds of nature are random and meaningless. After stating his counter-argument that there is continual music, rather than noise, in the sounds of nature, Thomas discloses the train of thought that brought him to this conclusion. (See the outline that follows.)

Accepted Belief: The sounds we make are random-sounding, accidental, incidental. We have trouble selecting meaningful signals from them.

Counter-argument: Underlying these sounds is a continual music.

Support of Counter-argument: (examples that bring into question features of accepted belief)

-Termites make percussive sounds by beating their heads.

-Prairie hens make a drumming sound by beating their feet.

-Gorillas beat their chests for certain kinds of discourse.

-Birdsong contains a variety of motifs.

Address of Opposition's View: These individual parts may not sound like music by themselves. They must be viewed as a part of music, "like an isolated section of an orchestra" (26) that when combined with other sounds of nature, "lift[s] us off our feet" (26).

Proposal of New Theory/Model: The "grand canonical ensemble" of nature, the rhythms of insects, the pulsing runs of birdsong, the descants of whales, the vibrations of locusts in migration, and the tympani of gorilla breasts illustrate the urge to make a kind of music that organizes matter into "an increasingly orderly state" (27).

Clinching Statement: The term "grand canonical ensemble" that applies to this organization of matter into order, in both thermodynamics and music, "would do for what I have in mind" (28).

Figure 5. Outline of Thomas' Process of Discovery in "The Music of This Sphere."

He recounts the numerous examples that, one by one, brought the accepted belief into question. He also demonstrates that to reach his conclusion, he had to refute some of the known arguments of those holding the accepted belief. Thus, he responds to the argument (that these individual parts do not sound like music) with his argument that it is when the sounds are heard together that they make music.

Furthermore, in his process of discovery, Thomas suggests that mere negation of the accepted belief is not enough. He proposes a new theory, that the urge to join sounds in music reflects the drive to organize matter into "an orderly state" (27). He also suggests that he is a nonconformist in his choice of thermodynamics as a model to illustrate this drive for order in music. He suggests that this drive for order by way of music is like the flow of energy from the sun by way of the earth. In a nonequilibrium state, the solar energy does not flow to the earth and radiate away; it is thermodynamically inevitable that "it must rearrange matter into symmetry, away from entropy" (27). He concludes, in his clinching statement, that music and thermodynamics now both share the term "grand canonical ensemble" to refer to this working together of the parts of nature to create order.

Other essays in which he communicates his process of discovery follow a less structured process of development.

For instance, in "Social Talk," Thomas does not reveal his focus until well into the essay. In this essay he wanders through several pages of discussing communication among ants. He moves to a discussion of how humans are like ants and then focuses on language, the characteristic that distinguishes humans from the rest of living things.

By revealing his particular process of discovery in this and many of his other essays, Thomas emphasizes the importance, not of his conclusions, but of the important process of discovery that stimulates thought. By showing his process of discovery, he adds another interesting element of his persona--that of the non-conformist who must not always have answers but who is comfortable with the search for them.

Opinion and Personal Preference.

Thomas also develops his subjects and communicates persona by expressing his opinions and personal preferences. In his essay on "The Technology of Medicine," Thomas gives his opinion on the technology in medicine. He places special importance on the first level of technology in medicine which he calls a "nontechnology," for it actually does not involve technology at all but is, nonetheless, indispensable, according to Thomas. This level involves the "standing by" part of medicine, supporting those patients for which nothing more can be done. With his

explanation of this kind of therapy, he also expresses the value he places on the former days of medicine when the physicians used to stand by the "bedside of patients with diphtheria, meningitis, poliomyelitis, . . . and the rest of infectious diseases that have since come under control" (36-37).

In "Autonomy" he frankly gives his opinion of a kind of technology that claims that people will soon be able to teach their kidneys to change the rate of urine formation, raise or lower blood pressure, change their heart rates, and write different brain waves. His clear response is "You can have it [technology]." He further explains his preference for allowing his body to work as it will.

> . . . I think it best to stay out of this business. Once you began, there would be no end to the responsibilities. I'd rather leave all my automatic functions with as much autonomy as they please, and hope for the best. Imagine having to worry about running leukocytes, keeping track, herding them here and there, listening for signals. After the first flush of pride in ownership, it would be exhausting and debilitating, and there would be no time for anything else. (79)

Thomas similarly communicates personal preference in developing his exploratory subjects. His numerous allusions to music, language, and insects demonstrate his partiality to these subjects. In "The Music of This

Sphere," he finds, in spite of the complex, random-sounding noise that abounds in the environment, a "continual music" underlying all other signals. He regards the beating of feet by prairie hens, rabbits, and mice, the banging of the woodpeckers' heads, the ticking of the beetles abdomen when striking the ground, as all part of the "grand canonical ensemble" (28). Moreover, Thomas has a particular preference for Bach, for he mentions him on several occasions, even suggesting in "Ceti" that the safest language to use in communicating with life on other planets is music, ideally, Bach. He communicates his zeal for Bach in this essay:

> I would vote for Bach, all of Bach, streamed out into space, over and over again. We would be bragging, of course, but it is surely excusable for us to put the best possible face on at the beginning of such an acquaintance. (53)

Thomas combines his enthusiasm for both language and insects as he notes the similarities in building a language and building a termite's nest in "Living Language." He also finds that language is alive, like an organism, and comments that <u>living</u> is more than an abstract metaphor; it indicates how words function as the cells of language, "moving the great body, on legs" (158). In "Antaeus in Manhattan," he shows his preoccupation with ants, termites, bees, and a plethora of other insects by opening with the statement: "Insects again" (62). By communicating his opinions

and personal preferences to his audience, Thomas helps to decrease the distance between reader and writer, for he allows the reader to see behind the face of the learned scientist to the man who likes Bach and insects, just as another man might prefer stamp collecting or a day at the theater.

Thomas' Interest in Humankind

In addition to showing an appreciation for exploratory subjects, Thomas also uses rhetorical techniques to communicate his interest in human nature. He illustrates his keen awareness and appreciation of typical human behavior through numerous instances of personification. He also shows a concern for his audience's understanding of his text with generous use of examples. Futhermore, Thomas reveals aspects of his own human nature through his use of humor and his expression of the feelings elicited by scientific subjects. Therefore, Thomas' persona deviates significantly from the persona of traditional scientists who typically exclude their personal feelings, eschew humor, and are careful not to allow non-human things perform human actions. Thomas, instead, communicates through personification, examples, humor, and expression of feelings, the persona of a man who has fun with science and one who is as concerned with the persons as the things of science.

Personification

The granting of human qualities to non-human forms offers one of the best indications of Thomas' person-oriented approach to science. Hence, his mitochondria in "Organelles as Organisms" "run the place" and have families. Bacteria in "Germs" are preoccupied with browsing, and the earth in "Ceti" has a nervous system, ganglions, and "dish-shaped sensory organs" (51). In "On Societies as Organisms," ants farm, raise livestock, launch armies, and capture slaves while slime mold vote "straight Republican" (14). Likewise, cells walk through the park, sense, think, and listen to music in the essay, "The Lives of a Cell."

Another way in which Thomas personifies non-human beings is by having them talk. The dancer bee instructs another bee to go "south-southeast for seven hundred meters, clover--mind you make corrections for the sundrift" (14). The female moth tells the male moth, "At home, 4 p.m. today," and when she releases an explosion of her special fragrance, he replies, "Bless my soul, what have we here!" (18).

With these and other numerous examples of personification (see TABLE I on pages 89-92 for other instances of personification), Thomas shows his own interest and appreciation for the typical kinds of human behavior. Also by giving human qualities to non-human forms of life, he reiterates his theme of how connected and alike are all living things.

Examples

With his generous use of illustration and example, Thomas shows a concern for his lay audience and their understanding of his text. (See TABLE I on pages 89-92 for a complete account of the essays developed by example.) Thomas often begins an essay with an illustration to which his audience can relate and with which he can demonstrate an abstract concept. Thus, in his second essay, "Thoughts for a Countdown," he describes, much as one observing the occasion on television, the ritual of astronauts returning from the moon, "waving enigmatically, gnotobiotically, to the President from behind glass panes, so as not to breath moondust on him" (5). He further describes the quarantine the astronauts encounter in the days following their return, to show how ridiculous is this "antiseptic ceremony" (5) that attempts to protect humans from the invasion of any alien matter. Thomas shows that the human being is not exclusive or superior, but instead "every creature is, in some sense, connected to and dependent on the rest" (6).

Typically after opening with such an illustration as the one provided by astronauts, Thomas states his thesis, which he supports with numerous examples from science. He chooses simple examples to which the audience can relate, the most frequent of which are "social" insects such as ants and termites. In "On Societies as Organisms," he

describes the movements of medical scientists at an annual meeting as the swarming and darting of insects: "There is the same vibrating, ionic movement, interrupted by the darting back and forth of jerky individuals to touch antennae and exchange small bits of information;" (11). He adds examples of how humans are like ants, termites, bees, slime mold, and fish, for these creatures all farm, raise food, launch armies into war, use sprays to confuse enemies, capture slaves, and "do everything but watch television" (12).

Thomas does not limit his methods of explanation to illustration and example, but also uses other forms of explanation such as metaphor, simile, and analogy.[5] Though I discuss metaphor and simile in more detail in my discussion of style in Chapter V, I also mention them here to illustrate his desire to use a variety of methods to translate unfamiliar topics into familiar terms for his audience. By using the metaphor, engine, to refer to organelles in "Organelles as Organisms," Thomas clarifies the function that organelles serve in the human body as the source of power. In "Germs" he illustrates the powerful human defense mechanisms against disease by calling them "Pentagons" (94). In "Autonomy" he also uses the simile of riding a bike: "experimental psychologists have recently found that visceral organs can be taught to do various things, as easily as a boy learns to ride a bicycle" (76). In "The World's Biggest Membrane," Thomas illustrates

the importance he places on the atmosphere by using a simile: "the atmosphere is as much a part and product of life as wine or bread" (173-74). He further accounts for the way species evolve by comparing evolution to the process by which jokes circulate: "Maybe the thoughts we generate today and flick around from mind to mind, like the jokes that turn up simultaneously at dinner parties in Hong Kong and Boston, are the primitive precursors of more complicated, polymerized structures that will come later. . ." (163).

Also in his attempt to communicate on the level of his audience, Thomas occasionally employs the analogy, or the use of a metaphor throughout several sentences, paragraphs, or the entire essay. To illustrate how language grows in "Living Language," Thomas uses the analogy of termites building a nest:

> Grasse placed a handful of termites in a dish filled with soil and fecal pellets. . . . Nobody stood around in place and gave orders or collected fees; they all simply ran around, picking up pellets at random and dropping them again. Then, by chance, two or three pellets happened to light on top of each other, and this transformed the behavior of everyone. Now they displayed the greatest interest and directed their attention obsessively to the primitive column, adding new pellets and fragments of

> earth. After reaching a certain height, the construction stopped unless another column was being formed nearby; in this case the structure changed from a column to an arch, bending off in a smooth curve, the arch was joined, and the termites then set off to build another.
>
> Building a language may be something like this. . . primitive. . . men. . .clustered together, making random sounds. . . . (157-58)

In "Computers" he also uses analogy, comparing humans to computers who are driven by information and are becoming a grid, "a circuitry around the earth" (131). With his use of metaphor, simile, and analogy, Thomas shows concern for his audience by translating abstract, philosophical topics, such as language and and human behavior, into concrete terms with which people are familiar.

In addition to his concern for his audience, Thomas also communicates a respect for his readers through his attitude toward explanation. Thomas illustrates and explains without talking down to his audience, for he does not always define technical terms, but instead challenges the reader to discern from his text the relevance of these technical terms. Hence, in "The Fear of Pheromones," Thomas begins with a question that implies knowledge of the word <u>pheromone</u>: "What are we going to do if it turns out that we have pheromones?" (16). In his analysis of Thomas' book, Fred White observes: "Thomas

seems to be saying between the lines, look up every other word if you need to. . .; once you have learned what mitochondria are and can understand the difference between prokaryotic and eukaryotic cells, you will be all the wiser for it" (34). Yet Thomas does more defining than White suggests. When using terms like pheromones, he explains the term within the context of the essay in such a way that the audience can understand the general meaning of the term. For example, in the chapter on pheromones, Thomas follows his introductory question with two paragraphs of background information and examples of how pheromones work.

With examples, illustrations, and analogies that support technical subjects like pheromones, Thomas shows his respect for his audience's intelligence and communicates the persona of a knowledgable scientist who is also committed to illustrate and clarify at all points of possible confusion.

Humor

Thomas' frequent use of humor (See TABLE I on pages 89-92 for a list of essays using humor) demonstrates his own fun-loving approach to science and his awareness that the lay audience could benefit from occasional respites from serious scientific subjects. Furthermore, Thomas often uses humor for a purpose; through satire, understatement, and personal jibes, he shows the ridiculousness of many of

our beliefs and values. In "Your Very Good Health," Thomas makes fun of the health-care delivery system that proposes to make this country a "sort of gigantic spa, offering, like the labels on European mineral-water bottles, preventives for everything from weak kidneys to moroseness" (97). To better illustrate the absurdity of a kind of technology that proposes to take charge of our very brain waves, Thomas satirically states, "It is extremely important, I know, and one ought to feel elated by the prospect of taking personal charge, calling the shots, running one's cells around like toy trains" (77). Yet his response remains "You can have it" (77). He identifies with lay people, who would panic if given control of themselves, as he makes fun of himself and his fear of this technology:

> My trouble, to be quite candid, is a lack of confidence in myself. If I were informed tomorrow that I was in direct communication with my liver, and could now take over, I would become deeply depressed. I'd sooner be told, forty thousand feet over Denver, that the 747 jet in which I had a coach seat was now mine to operate as I pleased; at least I would have the hope of bailing out, if I could find a parachute and discover quickly how to open a door. Nothing would save me and my liver, if I were in charge. For I am, to face the facts squarely, considerably less intelligent than my liver. (78)

In this chapter he continues to make himself the focus of his humor, further lessening the distance between himself and the reader by admitting his weaknesses. When entertaining the idea of what he would do if given control of his brain, he comments: "There are several things I would change. . . certain notions I'd just as soon didn't keep popping in, trains of thought that go round and round without getting anywhere, rather like this one" (78-79). By admitting a problem shared by many people, the tendency to ramble, Thomas identifies with his audience, inviting the audience to laugh with him in a joint recognition and appreciation of human nature.

Thomas uses a similar example of humor and his tendency to get carried away in "Living Language." After giving several pages of explanation on how language grows, showing the derivations of words such as man, doctor, and earth, he ends his essay with a summary of the chapter but cannot resist showing the derivation of the words in his summary:

> That should be enough (nek, to attain, becoming ganoga in Germanic and genog in Old English, also onkos in Greek, meaning burden, hence "oncology") to give you the general (gene) idea (weid becoming widesya then idea in Greek). It is easy to lose the thread (from ter, to rub, twist--possibly also the root of termite). Are you there? (164)

He continues to make fun of himself indirectly by making fun of his profession. After explaining the disappointing exploits of a researcher in Uganda, who is trying to gather data for his book on the Iks (a nomadic tribe in northern Uganda, a tribe that defecated on his doorstep, snatched his food, and "hooted dislike at him"), Thomas comments with understatement, "one senses, between the lines, that the scholar is not himself the world's luckiest man" (127). With numerous instances of humor throughout the twenty-nine essays in The Lives of a Cell, Thomas communicates the fun and enthusiasm with which he approaches science and furthermore achieves his aim of showing people that "it's great fun to look at it [nature]" (Dowdy 15).

Emotion

Enthusiasm for his work is one emotion that Thomas communicates on almost very page of his book. He frequently expresses awe of the world around him: "We are, after all, a planet where the rain contains vitamin B_{12}!" (10). Similarly, he is excited by the uncertainties of his work: "If you hear the word, 'Impossible!' spoken as an expletive, followed by laughter, you will know that someone's orderly research plan is coming along nicely" (140). Yet his most frequent expression of enthusiasm is over the social nature of his work and his discovery of the symbiotic relationship of all of nature. In "On Societies as Organisms," he comments:

> We like to think of exploring in science as a lonely, meditative business, and so it is in the first stages, but always, sooner or later, before the enterprise reaches completion, as we explore, we call to each other, communicate, publish, send letters to the editor, present papers, cry out on finding. (16)

With comments such as these quoted, Thomas shares with his audience the excitement he feels for the scientific enterprise, both the disappointments and discoveries, the certainties and the stimulating ambiguities.

Thomas also communicates the persona of the concerned physician, as best described in his essay "The Long Habit." In his discussion of death, he empathizes with the feelings of both the dying and those who watch death. After closely observing the dying process, he finds that for those approaching death, "dying is an all-right thing to do" (60). He comes to understand how those who have had near-death experiences report that the only painful part of the process was in being interrupted by the doctors' attempts at resuscitation. Also, he shows his ability to look at death from the patient's viewpoint, by relating the experiences of one woman who found the experience of coming back from the dead as a harrowing experience: "she deeply resented the interference with her dying" (60). Yet Thomas also shows compassion for those who must watch loved ones die and speaks with regret of the days past when the "most

important of all the services of a good doctor [was] to be on hand at the time of death and to provide comfort, usually in the home" (58). Hence, in his discussion of death, Thomas identifies with the feelings of others as he also considers his own role in the dying process, both as a physician and as one who shares with the majority of human beings, a fear of this "solitary. . . enemy" (58).

The nature of the essay allows Thomas to pursue different kinds of content in The Lives of a Cell. He focuses on the exploratory rather than the definitive, verifiable subjects of science. Moreover, by exploring his rhetorical techniques, not as stylistic devices, but as significant aspects of his content, we can isolate the elements of his content that contribute to his particular persona. Through his use of questioning, discovery, and opinion, he invites his audience to join his exploration of science and reveals to them his own uncertainties and personal preferences. With his use of personification, example, humor, and emotion, he identifies with the concerns of his audience and acknowledges his interest in humankind.

TABLE I

EVIDENCE OF PERSONA IN THE CONTENT OF
THE LIVES OF A CELL

Chapter	Subject	Appreciation of Exploratory Subjects			Interest in Humankind			
		Question	Discovery	Opinion	Per.*	Example	Humor	Emotion
"The Lives of a Cell"	All living things are interconnected	X		X	X	X	X	
"Thoughts for a Countdown"	Every creature is dependent on the rest.			X	X	X		
"On Societies as Organisms"	Separate animals join to form organism.			X	X	X	X	X
"A Fear of Pheromones"	Pheromones are shared by all living creatures.	X				X		
"The Music of This Sphere"	There is a continual music in nature.			X	X	X		X
"An Earnest Proposal"	Machines threaten to control human behavior.	X	X	X		X		
"The Technology of Medicine"	There are three levels of technology in medicine.	X		X		X		
"Vibes"	We are all marked by signaling mechanisms.				X	X		

* Per. = Personification

TABLE I (Continued)

Chapter	Subject	Appreciation of Exploratory Subjects			Interest in Humankind			
		Question	Discovery	Opinion	Per.*	Example	Humor	Emotion
"Ceti"	Interstellar communication is now possible.	X	X	X	X	X		X
"The Long Habit"	People have difficulty dealing with death.	X	X	X		X	X	X
"Antaeus in Manhattan"	All living things are interconnected.			X	X	X		X
"The MBL"	The MBL is a model for considering the effects of a social species.			X	X	X		X
"Autonomy"	Technology threatens to control humans.	X	X	X	X	X		
"Organelles as Organisms"	All things are interconnected.	X		X	X	X	X	
"Germs"	Disease results from failed symbiosis.		X	X	X	X	X	X
"Your Very Good Health"	The health care industry works against the human body.	X		X		X	X	
"Social Talk"	Language distinguishes humans; interconnectedness	X	X		X	X		
"Information"	Capacity for information linked to capacity for language.	X		X	X	X		

* Per. = Personification

TABLE I (Continued)

Chapter	Subject	Appreciation of Exploratory Subjects			Interest in Humankind			
		Question	Discovery	Opinion	Per.*	Example	Humor	Emotion
"Death in the Open"	Death is a part of the symbiotic cycle of life.	X	X	X		X		X
"Natural Science"	Science is a social activity.			X		X		X
"Natural Man"	Earth and all its parts are linked in symbiosis.	X	X	X	X	X		X
"The Iks"	Humans have not learned to live together.			X		X	X	X
"Computers"	Human collective behavior distinguishes them from machines.			X	X	X	X	
"The Planning of Science"	There is a great difference between the pace of basic science and applied science.	X		X		X		
"Some Biomythology"	Myths are necessary for society.			X	X	X		
"On Various Words"	Language is the most collective, programmed thing humans do.			X		X	X	X
"Living Language"	Humans are linked through language.	X		X	X	X	X	X

* Per. = Personification

TABLE I (Continued)

Chapter	Subject	Appreciation of Exploratory Subjects			Interest in Humankind			
		Question	Discovery	Opinion	Per.*	Example	Humor	Emotion
"On Probability and Possibility"	The notion of a unique self is myth.			X	X	X	X	
"The World's Biggest Membrane"	The sky is the grandest product of collaboration in nature.			X	X	X	X	X

* Per. = Personification

Notes

[1] I analyzed the content generated by these rhetorical devices and did not treat them, in this chapter, as stylistic devices. For example, I do not discuss Thomas' use of questions as a stylistic device for transition, but focus on the content of his questions and how they develop the exploratory nature of his discourse.

[2] All quotations, unless otherwise noted, come from the Bantam, 1974 edition of The Lives of a Cell. I chose this edition because it is the only available paperback edition.

[3] Kinneavy shows how users of the terms exploration and scientific have distinguished between the two terms. Drawing from the philosophers, rhetoricians, and scientists from Antiquity to the present century, he shows that scientific discourse relies more heavily on demonstration, testing, justification, and verification while exploratory discourse relies on opinion, discovery, invention, analysis, and inquiry (97-98).

[4] In this paper I define illustration as Thomas' use, in the opening paragraph, of an instance from everyday life. Often this instance seems to have no apparent relation to the title of his essay, but during the course of the essay, Thomas relates the instance to the scientific subject he discusses.

Example, though similar, does not refer to these opening instances, but relates to the specific cases from science that he uses throughout each essay to support his thesis.

[55] I define simile as a comparison using like or as. I define metaphor as either a literal comparison, using a form of to be, or as an implied metaphor, in which the tenor, or the subject to which the metaphoric word is applied, is not specified, but is implied by the verbal context. Analogy is an extended metaphor, used through several sentences, paragraphs, or an entire essay.

[56] Pheromones, according to Webster's Ninth New Collegiate Dictionary, are chemical substances produced by an animal that serve as a stimulus to other individuals of the same species for a behavioral response.

CHAPTER V

STYLE COMMUNICATES PERSONA

"Style is the man," according to Georges Louis Leclerc de Buffon in a speech to the French Academy 250 years ago (Tichy 261). These words continue to echo in definitions given by scientific writers who define style as the personality and character of writing (Tichy 261), the writer's individual characteristics, (Whitburn 350), and the aggregate of qualities that allows us to discriminate between one person and some other (King 114). In this chapter, I identify those characteristics of Thomas' writing style that distinguish his personable voice. My focus is on what Broadhead calls "discourse style," which involves vocabulary, usage, sentence structure, and sentence length because these are the characteristics that most clearly identify persona. I do not attempt to identify the editorial aspects (format, arrangement, documentation) or presentational aspects (layout, typeface, graphics) of Thomas' style (Broadhead 218).

My initial observation of Thomas' style was that its informality contributed to his more personal voice. Therefore, to determine the degree of his informality

and what stylistic elements communicate this informality, I analyzed both those stylistic elements that would contribute to informality and those that would lessen the informality. By using computer stylistic analyzers, I assessed his paragraph, sentence, and word length, his use of personal pronouns, prepositions, passive voice, jargon, and nominalizations. I supplemented this analysis with my own assessment of his figurative language and phrasal verbs. In the chapter that follows, I describe my procedure for analyzing Thomas' book, report the results of my analysis, and from these results, draw conclusions about his style and how it communicates his persona.

Procedure for Analysis

Preliminary Considerations

I began my analysis of Thomas' style by making some preliminary observations and establishing some of the definitions with which I would work. I first identified two styles of writing: informal style (one that allows for the greatest amount of authorial intrusions or persona) and formal, scientific style (one that attempts to obscure all evidences of persona). I expected to find many of the characteristics of informal writing in Thomas' book, for he is writing to a general audience, but I also observed that some elements characteristic of scientific style are still evident in his writing. Therefore, I defined the most prominent characteristics of each of these styles (see Figure 6) to determine where, on

a continuum between the two, I would place Thomas' style.

Informal|----------|Scientific

Simple words	Technical terms
Short, varied sentences	Long, complex sentences
Active voice	Passive voice
Figurative language	Nominalizations
First person	Third person
Phrasal verbs	

Figure 6. Diagram of Informal and Scientific Writing Styles.

Furthermore, I approached these two norms as measures of distance between the writer and the audience, as indicators of a writer's openness for communicating persona. Writers with an informal style attempt to make readers feel close (Irmscher 136). They accomplish this by using simple words, a variety of sentences (136), figurative language, and phrasal verbs[1] (Guth 426), and by supplying agents to actions, usually in the form of first person speakers and personal pronouns. Because scientists, on the other hand, seek a style that will most accurately and objectively report information, they create a vast distance between writer and reader and communicate the persona of a detached, objective writer. In an effort to remain objective, scientists seek those stylistic elements that draw less attention to the writer and more attention to the text. They use passive voice and nominalizations because with these elements, writers can focus on the objects rather

than the doers of actions (Kinneavy 177). They also freely use technical language that will most accurately convey their scientific matter and characteristically report their information in the more objective third person.

To characterize more specifically how Thomas creates an informal style and personal relationship with the reader when using such scientific characteristics as passive voice, nominalizations, and technical language, I analyzed the following elements of his style:

- word length
- sentence length
- number of prepositions
- number of personal pronouns
- figurative language
- passive voice
- technical language
- nominalizations
- phrasal verbs.

I chose these nine elements because they appeared to be the dominant characteristics of Thomas' style and because they all directly or indirectly point out the persona the writer wishes to communicate to the audience and the distance he or she wishes to establish.

Computer Analysis

To make my analysis more consistent and time-efficient, I used a computer program to analyze paragraph, sentence, and word length, number of prepositions, number of personal pronouns, passive voice, and jargon. I chose Grammatik III to analyze these elements because, while most computer style analyzers generate word, sentence, and paragraph length, Grammatik III

offers a more sophisticated way of finding passive voice. Grammatik III marks not only passive voice formed from regular verbs, but also marks those formed from irregular verbs, such as tear (passive, was torn). In addition, Grammatik III offers a usage check that searches for other usage problems. From the standard phrase menu of Grammatik III, I chose to mark the following elements that would communicate either an informal or formal, scientific style:

- hackneyed, cliche, or trite
- informal or illiterate
- jargon, technical, esoteric
- long-winded or wordy
- overstated or pretentious, and
- passive voice.

In addition to marking these phrase types, Grammatik III generates a Statistical Analysis that shows the count and percentage of passive voice patterns and prepositions. It collects information about how many sentences are in the document, how many words each sentence and paragraph has, and the average word length, in syllables and letters. The Word Usage Profile, an optional function of Grammatik, generates a list of the words in a document, in order of frequency of their use. By compiling the totals given for each pronoun used, I was able to determine the total number of personal pronouns Thomas uses in his book.

I analyzed these usage elements for each chapter of The Lives of a Cell. As a "marking" program, Grammatik III allowed me to view each of the usage problems, in the context of a sentence, before I marked it to be included on the final printout and Statistical Analysis. I instructed

Grammatik to mark and print the usage elements that I wished to note. The resulting printout listed all the usage elements, suggestions for correction, and the Statistical Analysis. As I analyzed each chapter, I found that the most common element marked was passive voice. The occurrences of hackneyed, informal, long-winded and overstated phrases were so few that they do not merit mention. Grammatik III marked no jargon or technical terms in Thomas' text.

After marking each chapter and generating the stastical analyses and word usage profile, I checked the results against my own search. Though I found that the word, sentence, and paragraph length, word frequency, and preposition counts were accurate, I found instances of jargon in Thomas' text that Grammatik III did not mark. I concluded that the scientific words Thomas uses are not in the Grammatik III dictionary. I also noted discrepancies with the passive voice totals. In some cases I could determine that Grammatik III would not mark passives if several words separated the to be verb from the participle. In other cases, there was no explanation for the omission of a passive voice. Therefore, I used RightWriter to analyze Thomas' technical terms and jargon, and analyzed Thomas' use of passive voice myself to get a more accurate assessment of the frequency with which he uses passive voice.

RightWriter, like Grammatik, is a "marking" stylistic analyzer. It generates a similar summary report and statistical analysis. In addition, RightWriter produces a

"Words to Review List" that consists of jargon and hard to understand words. The words noted as jargon were characterized by certain suffixes, such as ment, ial, tion, and able. While the words marked as jargon did not satisfy my definition of jargon (the words used in a specific discipline), many of them did satisfy my definition of nominalizations. The other words appearing on the "Words to Review List" were classified as hard to understand words. In this list were many of what I called jargon or technical terms. Hence, I reviewed the Words to Review List for nominalizations and technical terms. I omitted hard to understand terms that were not specific to the scientific discipline. I also omitted a few scientific terms that have become part of the general public's working vocabulary, such as antibiotic, cancer, stroke, pneumonia, arthritis, and penicillin.

After marking this list for nominalizations and technical terms, I compared the results against my own analysis of his essays. I found that the Words to Review List contained all of the technical terms, but that often fewer than half of the nominalizations appeared on the list. Therefore, because an accurate count of nominalizations was essential to my analysis of Thomas' style, I searched each chapter myself for nominalizations.

Non-Computer Analysis

After using Grammatik III and RightWriter, I determined that these computer analyzers would not accurately mark

passive voice or nominalizations. Two other elements I wished to analyze that computers could not evaluate were figurative language and phrasal verbs. Therefore, I conducted four separate analyses, one for each of these elements. In each case I highlighted the element for which I was searching. At the end of each analysis, I counted the highlighted terms and entered the total on the "Results of Stylistic Analysis" table found on pages 105-06. In each of these four analyses, I encountered limitations and problems specific to that stylistic element.

Passive Voice. In cases where I encountered a plural verb with one subject, I counted this form as one passive voice. In "The Lives of a Cell," an illustration of this case is: "We are shared, rented, occupied" (5). In cases where Thomas strings together several passive statements but gives the to be form only with the first passive statement, I interpreted the statements that followed as passive, with the to be form implied, for example: "Trails can be laid and followed, antagonists frightened and confused, friends attracted and enchanted" (18). I documented this sentence as having three passives, each with plural verbs.

Nominalizations. I defined nominalizations as nouns derived from verbs or adjectives (Williams 11). Hence, I marked nominalized verbs and nominalized adjectives, both of

which occur in significant numbers in Thomas' The Lives of a Cell. I did not, however, mark every word derived from a verb or adjective, but rather marked what I defined as unnecessary nominalizations, those words that would more clearly and economically be stated as verbs or adjectives. Hence, I marked nominalizations formed by the use of expletives: ". . .it requires long patience and observations to edit out the parts. . ." (22) and nominalizations created by using weak verbs, such as have in "have the arrangement" (28). I did not mark words like conversation that are usually more concisely expressed in the nominalized form: "Light social conversation prevails" (22). I also omitted from my list of nominalizations scientific terms that are more commonly and more concisely referred to in the nominalized form: radiation, abortion, evolution, natural selection, infection, and circulation.

Figurative Language. I restricted my search of figurative language to metaphor, simile, and personification. I chose these particular elements because they are the most commonly used ones in Thomas' writing. In searching for these examples of figurative language, I worked from the following definitions:

- A metaphor can be literal or implied.

An implied metaphor omits the tenor, or the subject to which the metaphoric word applies. When Thomas refers to "the rhythmic tympani of schools of mollusks" (26), he implies that he is comparing the sounds of mollusks (tenor) to music.

- Personification is a figure of speech in which non-human objects or abstract concepts are endowed with human attributes.

Phrasal verbs. The use of phrasal verbs is a characteristic of informal communication (Guth 426). These verbs consist of a verb form plus a preposition, such as "come on up."

By supplementing the computer analysis with my own search of these usage elements, I was able to provide more accurate information and gain a better understanding and perspective from which to evaluate the results.

Results of Analysis

The results of my analysis are shown in TABLE II on the following pages. (See also Appendices B, C, D, and E for lists of Thomas' phrasal verbs, figurative language, jargon, and nominalizations.) For each characteristic analyzed, I indicate both a total number of occurrences per essay and a total of that characteristic for the entire book. I also provide percentages of each characteristic, where appropriate, to give a better means of interpreting and comparing the results.

TABLE II

RESULTS OF STYLISTIC ANALYSIS

Essay	Total # of Words	Ave. Words Per Para[1].	Ave. Words Per Sent.[2]	Word Length		Phrasal Verbs		
				In Letters	In Syllables	Total # of Verbs	Phrasal	% Phrasal
The Lives of a Cell	965	85.7	20.9	4.5	1.5	90	9	10.0
Thoughts for a Countdown	1470	120.2	24.5	4.9	1.6	132	10	7.6
On Societies as Organisms	1683	120.1	27.1	4.8	1.6	139	5	3.6
A Fear of Pheromones	1231	111.5	28.6	4.9	1.6	89	5	5.6
The Music of This Sphere	1710	99.9	26.3	4.9	1.6	115	6	5.2
An Earnest Proposal	1342	94.7	26.3	4.7	1.6	96	5	5.2
The Technology of Medicine	1842	96.2	28.3	4.9	1.7	136	6	4.4
Vibes	1488	99.2	24.8	4.9	1.7	111	3	2.7
Ceti	1344	102.9	21.0	4.6	1.5	128	10	7.8
The Long Habit	1852	113.5	26.4	4.6	1.5	134	19	14.2
Antaeus in Manhattan	1234	75.3	25.1	4.8	1.6	93	10	10.8
The MBL	1691	111.5	27.2	4.8	1.6	124	11	8.9
Autonomy	1524	107.5	22.4	4.5	1.5	142	18	12.7
Organelles as Organisms	1614	87.7	20.4	4.7	1.5	167	10	6.0
Germs	1624	115.1	23.5	4.9	1.6	138	8	5.8
Your Very Good Health	1698	119.5	23.9	4.8	1.6	149	7	4.7
Social Talk	1375	125.0	25.0	4.5	1.5	115	7	6.1
Information	1311	119.0	23.8	4.8	1.6	114	10	8.8
Death in the Open	1067	95.9	21.3	4.3	1.4	95	10	10.5
Natural Science	950	67.8	22.6	4.6	1.5	97	3	3.1
Natural Man	1199	84.4	22.2	4.6	1.5	108	12	11.1
The Iks	996	76.0	15.5	4.7	1.6	139	5	3.6
Computers	1081	97.2	21.6	4.5	1.5	90	6	6.7
The Planning of Science	1691	112.3	21.6	4.9	1.6	172	17	9.9
Some Biomythology	1864	91.8	22.4	4.8	1.6	167	13	7.8
On Various Words	1754	86.4	21.6	4.7	1.5	170	17	10.0
Living Language	2208	84.8	21.2	4.7	1.5	104	12	11.5
On Probability & Possibility	1200	98.4	24.0	4.7	1.6	105	8	7.6
The World's Largest Membrane	1275	104.6	25.5	4.7	1.5	109	11	10.1
Ave. for book	1458	96.0	23.6	4.7	1.6	123	9.4	7.7
Standard Deviation	310	14.4	2.8	0.15	0.1	27.6	4.3	3.0

1 Para. = Paragraph
2 Sent. = Sentence

Prepositions		Personal Pronouns			Passive Voice		Figurative Language			Jargon	Nom.[6]
#	# of Prep. Per Sent.	# of Per. Pro.	# of First Pers.	% of First Pers. Pron.	#	% of Verbs	Met.[3]	Sim.[4]	Per.[5]	#	#
159	3.5	93	56	60.2	12	13.3	8	9	6	45	14
232	3.9	79	22	27.8	20	15.2	6	4	5	55	30
218	3.5	67	16	23.9	16	11.5	22	16	10	12	12
178	4.1	51	19	37.2	17	19.1	4	1	10	26	22
276	4.2	86	28	32.6	22	19.1	33	5	8	13	35
205	3.6	70	32	45.7	14	14.6	8	1	1	60	23
305	4.7	58	8	13.8	31	22.8	9	1	1	27	41
237	4.0	57	25	43.9	29	26.1	4	5	6	64	23
176	2.8	91	67	73.6	6	4.6	11	2	4	17	22
274	3.9	101	70	69.3	14	10.4	11	7	1	9	27
178	3.6	54	15	27.8	9	9.7	11	3	11	14	22
248	4.0	86	13	15.1	20	16.1	8	2	1	29	16
194	2.9	128	60	46.7	21	14.8	10	7	2	17	24
233	2.9	137	73	53.3	22	13.2	13	1	3	80	14
253	3.7	126	72	57.1	22	15.9	13	3	1	80	21
213	3.0	108	49	45.4	19	12.8	10	3	1	8	22
187	3.4	102	77	74.8	15	13.0	8	8	4	4	25
220	4.0	69	16	23.2	21	18.4	3	6	6	18	21
163	3.3	79	35	44.3	6	6.3	2	4	--	3	13
142	3.4	54	9	14.6	20	20.6	5	7	--	2	19
167	3.1	99	69	70.0	7	6.5	13	6	--	23	21
118	1.8	91	24	26.4	3	2.2	4	1	15	9	7
145	2.9	73	64	88.0	10	11.1	9	2	3	1	11
241	3.1	72	23	32.0	31	18.0	1	--	--	5	33
295	3.6	82	18	22.0	13	7.8	4	8	1	52	19
246	3.0	75	9	12.0	24	14.1	11	3	2	17	18
317	3.0	62	12	19.4	20	19.2	10	5	3	10	17
184	3.7	66	39	59.0	7	6.7	6	8	1	13	19
207	4.1	48	12	25.0	8	7.3	4	2	3	26	19
214.3	3.5	81.5	35.6	40.5	16.5	13.5	9.2	4.5	3.8	22.6	21.1
49.7	0.6	17.0	36.4	20.9	7.5	5.6	6.2	3.4	3.8	22.9	7.1

3 Met. = Metaphor
4 Sim. = Simile
5 Per. = Personification
6 Nom. = Nominalization

Thomas' average paragraph length, 96 words per paragraph, falls slightly below the norm of 100 words per paragraph, that Houp and Pearsall suggest for reports and articles (169). With an average sentence length of 23.6 words, Thomas' sentences fall toward the lower end of the scale suggested by Tichy. Tichy reports that sentences directed to educated adult readers average between twenty and thirty-five words (314). Thomas also writes consistently short, typically one- and two-syllable words. His number of phrasal verbs and prepositions is relatively consistent throughout the essays, with the number of prepositions, 3.5 per sentence, being higher that the norm of 2.3 preferred by the scientists in Wales' study (5). In the results of personal pronouns, the significant finding is the large percentage of first person pronouns (40.5% of personal pronouns are first person). While Thomas uses figurative language in every essay, the amount varies according to the subject matter.

Stylistic elements such as passive voice, jargon, and nominalizations are generally considered impersonal elements; however, Thomas does not use them with great frequency. His use of passive voice (13.5% of verbs) comes closer to the amount that Turk and Kirkman find in novels (8%) than in scientific writing (32%) [119]. Thomas' use of jargon and nominalizations appears to be moderate, although I have no statistical basis for judging the frequency of these elements in his writing.

Interpretation of Results

I conclude that Thomas' use of short words, moderate-length paragraphs, phrasal verbs, high percentage of first person pronouns, and figurative language communicate an informal writing style and personable voice. Thomas confirms that in writing these essays he purposely deviates from the scientific style of writing that he considers to be "non-writing" and "hideous prose" (Thomas, Interview). His use of the more formal stylistic traits such as passive voice and nominalization comes naturally from his long association with the scientific discipline as well as from his desire not to talk down to his readers (Thomas, Interview). As a result of Thomas' informal stylistic characteristics, he moves away from the objective, impersonal persona that this "hideous prose" creates and communicates the persona of the personable, creative, communicative doctor. In the discussion that follows, I show how I arrived at these conclusions about Thomas' persona.

The Personable Man

Thomas' style indicates his awareness that simplifying his text is not enough for his lay audience; he must

present his subjects in human terms. Thomas accomplishes this purpose by using stylistic attributes that approximate everyday language and by giving to his scientific subjects and abstract concepts, human attributes. Thus, through his frequent use of first person pronouns and phrasal verbs, he communicates the persona of a man engaged in an everyday conversation with his audience. With his use of personification, he shows an interest in typical human behavior.

Personal Pronouns. Thomas' frequent use of personal pronouns, particularly first person pronouns, is one of the most noticeable attributes of his style, for readers do not characteristically encounter this number of first person pronouns (40.5% of pronouns are first person) in discussions of scientific subjects, where personal pronouns are characteristically omitted. In scientific discourse scientists hold that any intrusion of the writer or reader will distort the subject matter (Kinneavy 173).

In addition, I found a significant amount of variation between the essays in the use of first person pronouns. The highest percentages occur in "Computers" (88.0), "Social Talk" (74.8%), and "Ceti" (73.6%), while the lowest percentages occur in "The Technology of Medicine" (13.8%), and "On Various Words" (12.0%). These percentages

indicate that Thomas uses more personal pronouns when discussing the connectedness of humans to science, as he does in all three of the essays with high percentages of personal pronouns. In the essays with low percentages of personal pronouns, he takes a more detached, scientific approach to his subject, in "The Technology of Medicine" defining the three levels of technology in medicine, and in "On Various Words" giving a detailed account of how specific words entered our language.

I also found a relationship between the percentage of personal pronouns and the frequency of passive voice, as shown in Table III below.

TABLE III

FREQUENCY OF FIRST PERSON PRONOUNS

COMPARED TO PASSIVE VOICE

Essay	First Person Pronouns(%)	Passive Voice(%)
"Computers"	88.0	11.1
"Social Talk"	74.8	13.0
"Ceti"	73.6	4.6
Total Average	40.5	13.5

All of these essays with high percentages of first person pronouns had a lower than average percentage of passive voice, with "Ceti" having one of the lowest percentages of passive voice (4.6%).

Phrasal Verbs. Phrasal verbs, such as "come on," reflect the relaxed tone of conversational language. While Thomas uses phrasal verbs in all of his essays, he uses them most frequently when discussing topics that would most likely occur in everyday conversations, such as words, ("On Various Words" and "Living Language"), fear of technology ("Autonomy"), and death ("The Long Habit" and "Death in the Open").

Personification. The frequency with which Thomas uses personification also communicates the personable nature of his persona. He most often gives human traits to one of his favorite specimens for observation, the insects. Two of his essays with the greatest amount of personification are "On Societies as Organisms" (14 occurrences of personification) and "Antaeus in Manhattan" (11 occurrences). Thus, he describes his insects as farming, raising livestock, launching armies, (Cells 12), rearing broods, taking slaves, and raising crops (Cells 64). An exception to this positive use of personification occurs in "The Iks" where Thomas uses 17 examples of personification to endow cities and nations with the negative qualities of people, like the Iks, who cannot live together.

The Creative Scientist

Thomas' use of other kinds of figurative language (metaphor and simile), in addition to personification,

shows his creativity in linking science to topics his audience can understand. Though the amount of figurative language varies in each essay, Thomas does use some form of figurative language in every essay. By doing so, he again deviates from the style of traditional scientific discourse that discourages these kinds of personal intrusions in the text.

The greatest amount of figurative language occurs when Thomas discusses some of his favorite topics, such as music ("The Music of This Sphere"--46 figures of speech) and insects ("On Societies as Organisms"--48 figures of speech). The essay with the least amount of figurative language is "The Planning of Science" in which Thomas discusses the scientific enterprise from the perspective of the observing, somewhat detached scientist.

Thomas' use of figurative language correlates with his use of jargon. In most cases where the amount of figurative language is high, the amount of jargon is low, as shown in Table IV below.

TABLE IV

FREQUENCY OF FIGURATIVE LANGUAGE COMPARED TO JARGON

Essay	Figurative Language	Jargon
"On Societies as Organisms"	48	12
"The Music of This Sphere"	46	13
Total Average	17.9	22.6

However, the two essays with the smallest amount of figurative language did not follow this pattern. Thomas uses only six examples of figurative language in "Death in the Open" and one in "The Planning of Science" while the examples of jargon are likewise low, three and five, respectively. The subject matter of these two essays likely accounts for the infrequent use of figurative language and jargon.

The Communicative Doctor

Other elements of Thomas' style suggest the persona of a communicative doctor, one who is more eager to express his meaning clearly than to impress his audience with his knowledge. Making his writing easier to comprehend are his shorter, simpler words; short paragraphs; average-length sentences; and prepositional phrases in place of noun strings. Thomas' average word length varies little from essay to essay with the overall average being 4.71 letters and 1.56 syllables. The great majority of Thomas' words are short, one-and two-syllable words, making his diction sharper and more direct.

Thomas also keeps his paragraphs relatively short. Though the length of paragraphs varies significantly from essay to essay, the average length of 96.0 words per paragraph is below the 100 words per paragraph recommended by Houp and Pearsall (169).

Although sentence length is not the only gauge for determining a sentence's complexity, it does affect the readability of a sentence. Tichy reports that sentences directed to educated adult readers average between twenty and thirty-five words (314). Thomas' average of 23.6 words per sentence falls well within the appropriate sentence length for general, educated readers.

According to the standard suggested by Wales' study, Thomas uses a greater than average number of prepositions. Thomas averages 3.5 prepositions sentence while Wales' study suggests that scientists prefer 2.3. While this number of prepositions can add bulk, it can also simplify noun strings characteristic of scientific writing. I found no noun strings in Thomas' essays, no "olfactory epithelia odorant receptors." Instead, Thomas simplifies his writing by using dependent clauses and prepositional phrases: "There may even be odorants that fire off receptors in our olfactory epithelia. . ." (46).

Through his style, Thomas portrays a persona that deviates significantly from the persona typically attributed to scientists. His frequent use of informal stylistic characteristics communicates the persona of an involved, personable physician rather than a detached, objective scientist. He shows the influence of conversational speech and communicates an

intimacy with his audience with his frequent use of personal pronouns, phrasal verbs, and personification. He adds interest and creativity through the use of figurative language that is typically omitted in discussions of scientific subjects. He demonstrates his awareness of and interest in his audience's understanding with his use of simple words, average-length sentences, and shorter paragraphs. With his moderate use of formal techniques such as passive voice, jargon, and nominalizations, he retains a professional voice, necessary to gain the respect of his audience. Thus, while Thomas' communicates a professional voice in The Lives of a Cell, he more significantly creates the persona of the personable doctor who openly and creatively invites his audience to enjoy his text.

Notes

[1] Phrasal verbs consist of a verb plus one or more prepositions, such as "come on."

[2] In the Word Usage Profile Grammatik III does not distinguish between *it* as a pronoun and *it* as an expletive. Because I did not evaluate the number of expletives in Thomas' writing, I did not subtract the number of times *it* was used as expletive from the total number of personal pronouns.

[3] I acknowledge that studies exist, such as Josephine Miles' *Style and Proportion,* that count the proportion of adjectives to nouns to verbs to connectives; however, this study does not provide relevant information on the specific stylistic elements I analyze.

CHAPTER VI

CONCLUSION

The persona of a writer is often difficult to identify, for persona emanates from a complex combination of factors in the writing situation. Yet persona exists in all writing, even in that of the most "objective" scientific writer. Persona is particularly evident in writers like Lewis Thomas who does not propose to communicate a particular persona, but whose persona comes naturally from his purpose in writing this book, "I wanted the essays to be fun to read" (Thomas, Interview). As a result, his fun-loving, enthusiastic attitudes and feelings toward his scientific subjects and audience clearly emerge through such elements as organization, content, and style in The Lives of a Cell.

Before examining the persona of this scientist writing to non-scientists, I first reviewed the scholarship on persona in scientific writing. I found a significant amount of scholarship written in the past twenty years on this topic and attribute this interest in the writer's persona to three movements:

Changing theories of reality

The rhetorical view of science

The rise of popularized science.

As a result of the work of Thomas Kuhn and Albert Einstein, scientists have begun to view reality, not as an absolute given, but as a product of their own creation. Because of growing doubts in an absolute reality, scientists assume a more active role in creating reality: their values, attitudes, and beliefs, therefore, inevitably shape the reality they create and record. Scientific writers have, therefore, begun to regard the persona of the scientific writer as inevitable in communicating scientific information.

Rhetoric is likewise moving away from the Aristotelian view of speakers/writers as passive observers of given truths to the current perception of speakers/writers as active creators of the reality they communicate. Rhetoricians apply cognitive theory to rhetoric to explore how writers filter, select, and organize the information they communicate. In light of the current views of reality and recent cognitive theories, the scientific world of verifiable facts can no longer be easily distinguished from the world of personal attributes and values. Hence, researchers on scientific writing have begun to portray science, not as an impersonal, isolated activity, but as a humanized, rhetorical, persuasive endeavor where "the test of scientific schema is as much the degree to which it wins the agreement of other scientists as the degree to which it coincides with observed physical reality" (Halloran 80).

Also contributing to the humanistic view of the scientist is popularized scientific writing which has developed in this century out of the need to humanize complex scientific information for general audiences. To achieve this purpose, scientists must present science in human terms, often revealing a more personal perspective toward scientific information.

A significant amount of research confirms this perception that the persona of scientific writing has changed. While some of these studies focus directly on persona as the ethos or voice of the writer, others refer to persona indirectly by way of related terms, such as personality, subjectivity, and creativity. Regardless of the terms used, these studies generally focus on persona as the attitude that the writer exhibits toward the subject and the reader. These studies, moreover, challenge the view that scientific writing is totally objective and instead suggest that the writer must adapt his or her persona to the audience and subject.

Much of this research on persona in scientific writing remains theoretical. Few studies have focused solely on how writers create persona. Hence, to aid my own analysis of how Thomas creates persona, I first identified the key elements of scientific and popularized scientific writing that affect a writer's persona, for Thomas has written extensively for expert as well as lay audiences, and I anticipated that his experience with both kinds of writing would affect his persona in The Lives of a Cell. The

purpose of scientific writing, to represent reality as accurately as possible for verification and duplication of research, demands that the writer's content, organization, and style reflect an objective, detached persona. On the other hand, because popularizers seek to humanize science for popular audiences, the writer and reader intrude more in the organization, content, and style of their text.

Thomas' persona in The Lives of a Cell offers a good example of how a personable, fun-loving approach to the subject and reader can humanize science for popular audiences. I chose Thomas as the subject for my study of persona because I found that he communicated an intimacy toward his text and audience not found in other popularizers of science, such as Gould and Sagan. Thomas himself confirms that he takes a completely different approach to this popularized writing, which he calls essay-writing (Thomas, Interview). He deviates from the scientific norms in organization, content, and style, thus moving away from the the characteristics of scientific writing that communicate an impersonal, objective persona. The essay form allows Thomas the freedom to organize the essay largely according to the process of his mind rather than according to the prescribed forms of scientific discourse. With this kind of organization, he communicates an openness to his readers, an invitation to observe the intelligent ramblings of his mind as he contemplates scientific subjects. Through his frequent use of the straw man pattern of

organization, Thomas communicates the persona of an iconoclast who challenges his audience to question accepted beliefs. Characterizing Thomas' style are a moderate use of such scientific stylistic elements as passive voice, jargon, and nominalizations. However, the more prominent characteristics of his style are the numerous instances of informal stylistic elements such as moderate-length paragraphs and sentences, short words, phrasal verbs, numerous prepositional phrases instead of noun strings, a high percentage of first-person pronouns, and figurative language. The elements of scientific writing do not occur with enough frequency to interfere with the clarity of his writing, but are reminders to the audience of the learned, respected profession to which he belongs. More importantly, his informal stylistic characteristics create the persona of a personable, creative doctor who is more interested in creating a rapport with his audience than with impressing them with his knowledge.

This paper has addressed three of the major components of writing (organization, content, and style) through which one popularizer of science creates persona. Yet there remain other questions and opportunities for research. Certainly other aspects of the writing situation affect the author's persona, such as purpose and audience. Although I have mentioned purpose and audience as they have inevitably arisen in my discussion of Thomas' writing, I have not examined these issues in detail; their effect on the author's persona appears to be so significant that each deserves a study in itself.

For instance, an insightful study would be to compare a piece of Thomas' scientific writing to one of his popularizations to determine how he alters his persona for the different audiences and purposes. Also, in studying audience and persona, one should consider the effect that the readers' attitudes, values, and beliefs have on the persona they assign to the author. Hence, can we assume that the creation of persona rests solely in the hands of the writer? Advances in cognitive psychology in determining both the cognitive and emotive activities of readers and writers during the communication process should be helpful in clarifying the relationship between readers and writers in creating persona.

Another related area of study would be to empirically investigate the effect that different personae have on readers. Investigators could have readers record their impressions of the author and identify the aspects of the text that contribute to that impression. How important are the facts that readers know about the author prior to reading the text? Do readers develop their impressions of the writer solely from the text? This kind of investigation should involve numerous samples of readers and would no doubt be time-consuming but insightful.

More importantly, we must consider in our research why the study of persona is significant in scientific writing. I suggest that this study of Thomas demonstrates ways to look behind elements such as organization, content, and style to determine how an author communicates persona through them. Moreover,

this analysis of Thomas' writing suggests that a more person-oriented, involved kind of persona is effective for humanizing scientific subjects for lay readers. In Thomas, this personalism follows naturally from his own enthusiasm for his work, his people-orientedness, and his willingness to openly share his enthusiasm for science with them. Thomas, therefore, illustrates both that the more humanistic, familiar approach to subject and audience are effective, particularly with the growing complexity of scientific subjects, and that the voice must emanate naturally from the writer. It is this humanness in Thomas' persona that invites the reader to a text that would otherwise be unapproachable and incomprehensible.

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APPENDIX A

BIBLIOGRAPHY OF LEWIS THOMAS' WORKS

Popularized Scientific Writing

Within each section of the following bibliography, Thomas' works appear in chronological order, by date of publication. In some cases, complete bibliographic information was not available, particularly for journals no longer in existence.

Articles*

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*In this section, I use the same abbreviations for journal titles as those used in Science Citation Index.

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APPENDIX B

LIST OF PHRASAL VERBS

In the following alphabetized list, each word appears only once in The Lives of a Cell, unless otherwise noted.

accounted for
acting out
added up
age away
allowed out
ask around
asking around
backing off
bailing out
beg off
begin with
believed in
bending off
blowing away
blown through
booming along
botched up
bounds around
budding off
built up
burst out
carried out
carries off
carry off
carrying through
closed up
code out
coding out
come in (2)
come out (2)
comes on
comes out
coming along (2)
coming in
count up
covered over
crowded together
cry out
cut down
cut off (2)
designed to
die away
done in
drawn back
drift away
drifting apart
dropped out
dying away
edit out
eke out
end up (3)
engaged in
explained away
extends back
face up
fades away
fetching in
fighting off
figure out
filters out
find out
fire off
flick around
fluffing off
found out
fuse together
gathered together
gave up
gaze down
get along
get down
gets around
getting along
give away
give up (2)
go along (2)

LIST OF PHRASAL VERBS (CONT)

go away
go back
go down (2)
go on (4)
goes on
going on
gone out
got around
grabbed up
growing out
hidden away
hold out
join up
joined up
killing off
know about
lag behind
lagged behind
laid down
lay out
laying out
let up
lined up (2)
listened to
living off
living out
locked up
look after
look around
look at
looked around
looked at
looked on
looking around
looking up
made up (6)
make out
make up (4)
makes up
move aside
moved in
ordered up
pass around (2)
passing around
peering down
pick up
picked up
picking up (2)
pieced together
points out
propped up
put down
put off
put on
put out
putting down
radiate away
radiate out
ran around
rounds up
run out (2)
running off
runs out
scared off
scattered about
scattered around
screened out
send off
send out
sending out
sends out
sent off
separated off
set back
set forth
set off (2)
set up
setting apart
settling down
share around
sharing around
shield out
shut in
shut out
shutting off
sit around
slow down
smell out (2)
sniff out
speed up
spreading out
springing up
squinted at
stand back
standing up
start off
stay out (2)
sticking out
stood around
store up (2)

LIST OF PHRASAL VERBS (CONT)

stores up
storing up
streamed out
stretching back
struck down
swarm in
swarm out
swing back
switch off
switch on (2)
switched on and off
take in
take over
take up
taken for
taken up (2)
taking on
tapping off
think through
think up (2)
thought out
throw up
thrown out
tides over
tie up
took on
travel down
tumbling over
tumbling out
turn on (3)
turn on and off
turn out (5)
turn up (3)
turned out (3)
turned up
turning up
turns out (3)
used to
veer away
wait out
wear out
worked out (2)
wrenched away

APPENDIX C

LIST OF FIGURATIVE LANGUAGE

The following list of figurative language is arranged by essay, in the order that it occurs in each essay.

"The Lives of a Cell"

Metaphor - Earth/membrane,* mitochondria/posterity, mitochondria/responsible lodgers, cells/ecosystems genomes/catalogues of instructions, viruses/agents of disease and death, evolution/biologic game environment/matrix of viruses.

Simile - Man/as lethal force, earth/like rising bubbles at surface of country pond or flights of fragile birds, humans as transient and vulnerable/as cilia, mitochondria/as much symbionts as the rhizobial bacteria in the roots of beans, centrioles and basal bodies are foreign and essential/as aphids on anthills, genes pass around heredity/as though at great party, viruses dart/like bees, earth/like a single cell.

Personification - Cells breath, walk through the park, sense, listen to music, think thoughts, genomes speak their own language.

"Thoughts for a Countdown"

Metaphor - Astronauts' return from space/ritual, astronauts' procession off the ship/choreography, bacteria/social animals, rhizobial bacteria/chief organ in nitrogen fixation, bacteria/specialized organs, transactions between animals/combat.

*In listing metaphors and similes, I give the tenor first (the subject to which the metaphoric word is applied) and the vehicle second (the metaphoric word itself). In some cases, there are several vehicles for the same tenor.

"Thoughts for a Countdown" (cont)

Simile - Bee dying/like a desquamated cell when removed from his hive, microbial communities extend to higher forms of life/as to seem like new kinds of tissue in plants and animals, inventions thought up/like proposals to be submitted for possible evolution, humans might have developed/as a kind of flowing syncytium over the earth.

Personification - Microbes are reared, bacteria exchange and barter, bacteria give instructions, Gorgonaceae bow out.

"On Societies as Organisms"

Metaphor - Medical scientists at meeting/aggregating clusters, scientists coming to meeting/swarmed there, scientists'meeting/assemblages of social insects, scientists'movement/vibrating movement of insects, scientists'movement/dart back and forth, scientists' communication/touch antennae, grouping of scientists/mass, group of scientists' arrangement/ single file (as do insects), collaborative work of scientists/nest, thousands of ants/an intelligence, ants/live computer, bees/organisms, bees/tissues, bees/cells, bees/organelles, bees/family, signal given by amebocytes/bell, herring/multi-fish organism, linkage of humans/circuits, accumulation of information/anthill, interconnections between humans/circuitry, information/current.

Simile - Mass of scientists cast out/like a trout-line, insects/like creatures from another planet, insects/ like crazy little machines, ants/like human beings, weaver ants hold their larvae/like shuttles to spin the thread, ant/like a ganlion on legs, ants shift work/as though given new orders by telephone, long lines of ants/like tentacles, termites react/as if alarmed, termites work/like artists, single bee out of the hive retrieving sugar is as much a part of the hive/as if attached by a filament, bees/like the viruses inside a cell, time of preparing for bees' swarming/as though the hive were involved in mitosis, agitated moving of bees/like granules in cell sap, beehive splits in two/like an egg, amebocytes converge and construct the slug/ as solid as a trout.

Personification - Ants farm, raise livestock, launch armies, use chemical sprays, capture slaves, engage in child labor, exchange information, dancer bee speaks: "south-southeast for seven hundred meters,. . ." amebocytes vote straight Republican, slimemold is ambitious.

"A Fear of Pheromones"

Metaphor - Boundaries/real estate, pheromones' signals/ message, twentieth century deteriorating/ running in concentric circles down the drain, human mind perplexed by advances in communication/ mind jelled.

Simile - Certain microbes eke out a living/like eighteenth-century musicians, producing chemical signals by ornamenting the products of their hosts.

Personi-fication - Pheromones give directions, pheromones inform creatures when and where to cluster in crowds, when to disperse, how to behave to the opposite sex, how to ascertain what is the opposite sex, how to organize members of a society, how to mark exact boundaries, female moth says: "At home, 4 p.m. today," male moth notes, male moth says: "Bless my soul, what have we here!"

"The Music of This Sphere"

Metaphor - Sounds of animals/light social conversation, activities of nature/party, signals of nature/ music, click of golf ball on spectrograph/ call of warning or signal of mating or announcement of territory, bats live in world of ultrasonic batsound/industrial machinery sound, gorillas beating their chests/discourse, birdsong/business communication, robin's song/motifs, notes of song/ syntax, variations in birdsong/repertoire, animals in nature/instrumentalists, songs of animals combined/orchestrated, animals/ensemble, songs of animals/counterpoint/balance/timbres/ harmonics/sonorities, songs of sea birds/descants, music of mollusks/rhythmic tympani, music of midges/ harmonics, humpback whales/singers, song of whale/ musical piece, rhythmic sounds/dance, sounds of nature/arrangement of the Brandenburg Concertos, sounds of nature/rhythms of insects/ pulsing runs of birdsong/descants of whales/ modulated vibrations of locusts/tympani of gorilla breasts/grand canonical ensemble/notation.

Simile - Sound of termite/resembles sand falling on paper, termite sounds occur in regular rhythmic phrases/ like notes for a tympani section, the thrush practices/like a virtuoso in his apartment, song is a dominant aspect of human biology/like speech, the songs of the humpback whale can be listened to

as a part of music/like an isolated section of an orchestra.

Personification - Bird's song is part of their working day, thrush sings for his own pleasure, the thrush starts a run, reaches a midpoint in the second bar, stops and goes back to begin over, the thrush is dissatisfied over inadequate singing, thrush changes notation of song, humpback whale celebrates, whale feels jubilation over hearing his song.

"An Earnest Proposal"

Metaphor - Interconnections of humans/circuits of computer, world/arrangement of adversary systems, arrangement of termites/ecosystem, termite ecosystem/arrangement of Byzantine complexity, importance of Myxotricha paradoxa/at the epicenter of ecosystem, construction of termite/arches and vaults, rhythm of flagellae/beat in synchrony, blue-green algae/inventors of photosynthesis.

Simile - Humans have planted missiles in the soil of Russia, China, and our Midwestern farmlands, like perennial tubers.

Personification - Computers are possessed of a kind of intelligence.

"The Technology of Medicine"

Metaphor - Technology Assessment/exercise, the supportive therapy of medicine/nontechnology (3), things done to compensate for effects of diseases/half-technology (3), breakthrough in technology/makeshift, professional personnel/platoon.

Simile - Asking for more basic research in biologic science/like asking for the moon.

Personification - Diseases for a list of the technologies of modern medicine/candidates.

"Vibes"

Metaphor - Creatures that ants capture/slaves/victims, odorants/Spartan compounds, vibrations of atoms/ vibratory song.

Simile - Humans are marked by chemicals/as unmistakably and individually as by the membrane surface antigens detectable in homografts of our tissues, minnows in a school behave/like interchangeable, identical parts of an organism, theories to explain olfaction are as numerous and complex/as those for immunologic sensing, we regard the olfactory bulb/as a sort of archeologic find, we speak of the ancient olfactory parts of the brain/as though they were elderly, dotty relatives in need of hobbies.

Personi-
fication - Ants have relatives, victims of ants panic, minnows and catfish have person-specific odor, imagine an existentialist minnow, guinea pig is famous, all forms of life spread welcome.

"Ceti"

Metaphor - Tau Ceti/candidate for the existence of life, sky/ local roof/membrane, earth/blue chamber/bubble of air blown by ourselves, earth/city, humans/Skinner pigeons, earth/Skinner box, solar system/spinning clocklike apparatus around us, meaning of information/thread, music/language.

Simile - Humans feel confined on earth/like outgrowing a small town in a small county, news of ourselves sent to other planets/like a mimeographed Christmas letter.

Personi-
fication - Planets carry on conversation, earth has nervous system, ganglions, and dish-shaped sensory organs,

"The Long Habit"

Metaphor - Death/indelicacy, living/addiction, humans' addiction to life/hooked on living, humans wear out/come unhinged, death/enemy, death/lights to out, signals that the body gives of death/word gets around, parts of body/provinces, death/the business, human consciousness at death/a memory for a biospherical nervous system.

Simile - Talking of death/like talking in mixed company about venereal disease or abortion in the old days, humans talk about death on a grand scale/ as though we were talking about bad weather, humans may be/like the genetically different lines of mice or Hayflick's different tissue-culture lines (programmed to die after a predeterimined number of days), flies age and die/like flies, humans maintain flickers of life for long stretches in one community of cells/as though we were keeping a flag flying, consciousness of the dead is separated off at the filaments of its attachment and drawn/like an easy breath back into the membrane of its origin.

Personification - Humans lead nature around by the nose.

"Antaeus in Manhattan"

Metaphor - Linkages between ants/circuits, anthill/organism, ants/Art Form, ants with New Yorkers/abstraction/ live mobile/action painting/piece of found art/ happening/parody/marvel, author going to museum/ migrate.

Simile - Bees and ants have no more life of their own/than a cast-off cell marooned from the surface of your skin, ants formed themselves into long, ropy patterns, extended/like writhing limbs, hands, fingers, across the sand in crescents, crisscrosses, and long ellipses, from one station to another, Art Form disintegrated/like one of those exploding, vanishing faces in paintings by the British artist Francis Bacon.

Personification - Termites are friendly; they watch their weight; are standoffish and are tempted. Ants inform other ants about the state of the world. The Hill of ants administers the affairs of the institution, coordinates and synchronizes the movements, rears broods, takes slaves, raises crops. Ants instruct us in the whole range of our institutional virtues.

"The MBL"

Metaphor - Growth of MBL/sprouting, leading biologists brought into field/ushered in, pharmaceutical industry has sensed opportunities/sniffed opportunities, trouble in summer program at MBL/institutional hell,

physicists' pessimism/look of doom, place to sit on the beach/hunching place, sounds of audience leaving meeting/jubilant descant, rumblings of audience leaving meeting/music.

Simile - The enterprises that we engage in collectively/ the things we build like wasp nests, local beach functions/as a sort of ganglion to MBL.

Personification - MBL has a mind of its own.

"Autonomy"

Metaphor - Allowing body to work autonomously/free fall, stop a fall/break a fall, cells touch/communicate, arrangement of organelles/ecosystem, being in control of body/calling the shots, cells might attack/swarm into ventricles, cells not working/ fluffing off, running the human body/this business, controlling leukocytes/herding them here and there, autonomic functions of body/internal environment.

Simile - Working a typewriter by touch/like riding a bicycle or strolling on a path, humans/automated like ants, visceral organs can be taught to do things/as easily as a boy learns to ride a bicycle, I should feel elated at taking charge of my body, running my cells around/like toy trains, if we took charge, our cells would resent it and swarm into our ventricles/like bees, if we took charge, we could delete notions, trains of thought that go round and round/like this one, to let go of the control of body, your fingers must let go on their own/like the opening of a flower.

Personification - Smooth-muscle cells give instructions and work by a schedule.

"Organelles as Organisms"

Metaphor - New contributions to science/blocks of information, starting at the beginning/from scratch, mitochondria/ little engines, mitochondria operated by me/or my cellular delegates/bits of my intelligent flesh, mitochondria/strangers, mitochondria/maternal passengers, chloroplasts/self-replicating lodgers, mitochondria and chloroplasts/master-slave arrangement, organelles have done what they are designed to do/they stick to one line of work, mitochondria, organelles, cells, etc./my estate, cells/strangers (2), cells/relatives.

"Organelles as Organisms" (cont)

Simile - Biologic revolution/like last century's industrial revolution.

Personification - Mitochondria and chloroplasts run the place, nuclei, microtubules, and neurons have families and run typewriters.

"Germs"

Metaphor - Spraying aerosol/explode clouds of aerosol, noses, mouths, underarms/privileged crannies, plastic/protector, human disease/demonology, bacteria/adversaries, our involvement with diphtheria/not adversary in a straightforward game, hemolytic streptococci/intimates, bacteria look around/browse. we fight lipopolysaccharide/turn on every defense/bomb/defoliate/blockade, centers of body that control defense mechanisms/Pentagons.

Simile - Humans wrap everything in plastic/like state secrets, insects have colonies of bacteria living in them/like little glands, doing heaven knows what but being essential, the microorganisms that seem to have it in for use turn out to be /like bystanders, strangers in from the cold.

Personification - The Limulus flies into panic when confronted by the signal of free molecules of endotoxin.

"Your Very Good Health"

Metaphor - Social scientists becoming interested in amount spent on health/swarm in to take closer look, health care industry/house of IBM cards, doctors/health providers, patients/health consumers, country/gigantic spa, the word about health care/incantation, internists and households/captive patients, encounter at breakfast table/house-call, father/family doctor, problems in health-care industry/bills to pay.

Simile - Health Maintenance Organizations are spreading out across the country/like post offices, the country might become a gigantic spa, offering/like the labels on European mineral-water bottles, preventives for everything, it is a distortion

"Germs" (cont)

to picture the human being/as a teetering, fallible contraption.

Personification - Health Maintenance Organizations distribute packages.

"Social Talk"

Metaphor - Beehive/spherical animal, real news in science/action of a pheromone, humans keep secret knowledge/private store, 3 billion humans/stupendous animal, humans have no choice/vote about being social, humans working together/droning away, languages come together/form nests, language endows meaning/houses us in meaning.

Simile - Members of some species so tied/as to seem the loosely conjoined cells of a tissue, social insects are/like this; they move and live in a mass, humans distribute information/as though it were a kind of essential foodstuff, humans build private store of knowledge and hide it away/like untouchable treasure, there are superficial resemblances in some of the things humans do together/like building glass and plastic cities, language is/like nest-building or hive-making, the universal and biologically specific activity of humans, language behaves/like an active, motile organism.

Personification - Animals have first-name relationship, languages behave, languages fuse and replicate.

"Information"

Metaphor - controls for living/templates, opening of wasp nest/door, new cluster of lymphocytes/a memory.

Simile - Morphogenesis of deep structures built into our minds, for coding out/like proteins, the parts of speech, correct grammar is as much a biologic characteristic of our species/as feathers on a bird, hundreds of people in concert hall listen to music/as though receiving instructions, people in concert hall concentrate/as though reading directions, wasp's capturing a caterpillar is as mindless/as an Ionesco character, bee observes sun/as though consulting his watch.

"Information" (cont)

Personi-
fication - Wasp has a single theory, approaches the capture of caterpillar as well-thought-out business, wasp imagines, lymphocytes guess, cells predict reality and guess.

"Death in the Open"

Metaphor - Dead bird/abstraction, symbiosis of life and death/ synchrony.

Simile - Dead animals on countryside appear/as fragments, we know about death/as a kind of abstraction, insects drift through the air/like plankton, the life of the earth dies in the same volume/ as the new life that dazzles us each spring.

"Natural Science"

Metaphor - Scientific enterprise/game, scientific enterprise/ not a systematic business, information/inflammation, process by which truth about nature arises/slow phrase of music, end of scientists' sharing information/sigh.

Simile - Scientists at work/like creatures following genetic instructions, scientists/like young animals engaged in savage play, an active field of science/like an immense intellectual anthill, scientific activity seems as random/as that of bees in a disturbed part of the hive, science comes in its own season/like pure honey, scientific activity looks/like aggression, scientific activity is/like a primitive running hunt.

"Natural Man"

Metaphor - Costs of environmental options/price tags, earth/man's personal property/garden/zoo/ bank vault/energy source, earth/loosely formed spherical organism, humans/owners/operators, humans/masters, humans/nature itself, humans/ large terrestrial metazoans, human/handyman for the earth.

Simile - Many alternatives (about the environment) to be sorted through/as in a market, humans arrive at a consensus/like an enormous committee, humans are as dependent on the rest of life/as are the midges or fish, humans are neither owners

"Natural Man" (cont)

or operators of the earth but we might see ourselves/as motile tissue specialized for receiving information, humans function/as a nervous system for the whole being, humans have grown into everywhere, spreading/like a new growth.

"The Iks"

Metaphor - Self-centeredness/Ikness, linkages of society/threads, the Ike/a committee, the Ike/a city.

Simile - The Iks sound/like abnormalities.

Personification - Cities defecate on doorsteps, leave rubbish, detest neighboring cities, give nothing away, build institutions for deserting elders; nations are greedy, rapacious, heartless, irresponsible, self-centered, withdrawn, bawl insults, survive by detestation, take joy in bad luck of others, celebrate the death of others.

"Computers"

Metaphor - Places to retire/sanctuaries/reservations, humans/software selves, machine/single individual, information/source of energy, information/energy system, humans/grid/circuitry/computer.

Simile - Machine as big/as Texas, mass of human minds behaves/like a coherent, living system.

Personification - Computers may become able to read magazines, vote, and think.

"The Planning of Science"

Metaphor - Disputing in science/the heat.

"Some Biomythology"

Metaphor - hybrids in bestiaries/lucky benignities, members for bestiaries/candidates, Myxotricha paradoxa/an assemblage, blepharisma/cannibalistic giant.

Simile - Mythical animals are as obsolete/as the old anecdotes in which they played their puzzling roles, mythical animals/like dreams, they may be as essential for

society/as mythology itself/as loaded with symbols, myths/like language, are as characteristic for human beings/as nest-building is for birds, mythical stories/like engrams are built into our genes, the membrane surrounding blepharisma disintegrates and comes loose/like a cast-off shell.

Personification - Cytoplasm dances.

"On Various Words"

Metaphor - Social insects/vast, multicreatured organisms, arrangement of social insects/Superorganism, idea of Superorganism/embarrassment, Superorganism/ an abstraction, human example to insects/lesson, DNA/grammar, neurons/syntax, changing of language/ metamorphosing/sprouting, design of words/ membranous, words/anthill

Simile - Language is/like the formation of anthill, the more powerful words are packed with layers of different meaning/like one-word poems, when new words unfold out of old ones, the original meaning hangs around/ like an unrecognizable scent.

Personification - Words have lives and carry on conversations.

"Living Language"

Metaphor - Termite nests/edifices, termite/New Yorker/resident of Los Angeles, termite's instructions for building/ blueprint, colony of termites/a huge contractor, words/cells of language, moving the body, on legs, way word is used/phenotype, word's deeply seated meaning/genotype, language/ancestor, word's derivation/travel.

Simile - Termite nests/like suburbs, interior of termite nest/like a three-dimensional maze, intricate arrangements or spiraling galleries, corridors, and arched vaults, ventilated and air-conditioned, termites/like contractors, deep structures of grammar are made of something/like cement, language is alive/like an organism, different words are/ like different species of animals

Personification - Termites give orders, collect fees. Words have parents.

"On Probability and Possibility"

Metaphor - The surprises of life/an altitude, activities of notion of one's own Self/myth, self/background noise, Art of Fugue and the St. Matthew Passion/ feathered wings/ apposing thumbs/new layers of frontal cortex.

Simile - Humans have become acclaimed to the altitude of surprise/like natives in the Andes, no one can lay claim to his own mind with anything/like the specificity stipulated by fingerprints or tissue antigens, bits of human thought are adrift/like plankton, thoughts we generate today are/like the jokes that turn up simultaneously at dinner parties in Hong Kong and Boston, or the sudden changes in the way we wear our hair, or all the popular love songs, process in art and science is done by passing the bits around from mind to mind, until something/like natural selection makes the final selection, all on the grounds of fitness, mutants have swept across the field of human thought/like comets.

Personi-fication - Brain carries on internal affairs in secret.

"The World's Biggest Membrane"

Metaphor - Earth/live creature, earth/membrane, covering of earth/canopy, result of lack of oxygen/strangling.

Simile - The atmosphere is as much a part and product of life/as wine or bread, comfort in knowing that the sky is there/like the random noise of rain on the roof at night.

Personi-fication - The earth is alive. The earth breathes. The sky breathes.

APPENDIX D

LIST OF JARGON

In the following alphabatized list, each word appears only once in The Lives of a Cell, unless otherwise noted.

abscissas
acids
adenyl
algae (5)
aliphatic
allelochemics
amebocytes (3)
ameboid
anaerobic
anatomic
anemia
anemone (2)
anemones (2)
anesthetic
antennae (3)
anthropologist (3)
antibodies
antibody
antigen
antigenic
antigens (5)
antiseptic
aplysia
apocrine (5)
atoms (5)
atp (3)
autonomic (2)
axon
B^{12}
bacilli
bacillus
bacteria (3)
bacterial (4)
bacteriophage (4)
bacterium
basal
basal bodies
bdellovibrio
bioacoustics (2)
biologic
biomedical (2)
biosphere (2)
blepharidos
blepharisma (5)
blepharismin (2)
bombykol (3)
brucella
bulb
bulbs
butyl mercaptan
capillaries
carapaced
carbohydrate
cell (5)
cells (14)
cellular
cellulose (2)
centrioles (3)
cerebral
chemotactic (2)
chemotherapy
chloroplasts (12)
chromatography
chromosomes
cilia (8)
cirrhosis
coagulable
coelenterate
convection
coronaries
coronary (3)
coronary-care
cosmological

LIST OF JARGON (CONT)

cristae
crustaceans
cyclase
cytoplasm (3)
cytoplasmic
defecate (3)
defecated
depolarization
dilate
diphtheria (2)
DNA (20)
ecology
ecosystem (5)
ecosystems (3)
electrocardiogram
electrodes (2)
electroencephalogram
electromagnetic (4)
electrons
endocarditis
endocrine
endocrinologic
endosymbionts (2)
endotoxin (6)
engrams
enteric
entomologist
entomologists (2)
entomology
entropy (2)
enzyme
enzymes (7)
epicenter
epinephrine
epithelia
epithelium
estradiol
estuarine
etymological
euglena
eukaryotes (3)
eukaryotic (3)
eutrophied
exaltolide
exotoxins
extraterrestrial (2)
fecal
flagellae (3)
forage
foraging
forebrains
formaldehyde
fungi (2)
fusion (2)
ganglion (2)
ganglions
gannets
gastrointestinal
gelatinous (2)
genes (3)
genetics
genome (3)
genomes (7)
geraniol
glaucus
glomeruli
glomerulonephritis
gorgonaceae
gorgonians
gram
haptene
helix
hemocyte
hemocytes (2)
hemolytic (2)
hemorrhage
hepatic
hexanoic
histocompatible
homeostasis
homografts
homologous
homology
hormones
humic
hypericin
iatrogenic
immune
immunity
immunologic (7)
immunology (2)
inflammation
INH
inoculated
interstellar
invertebrate
irradiation
isotopes
leghemoglobin
leguminous
Lepinotus inquilinus
leukocytes (5)

LIST OF JARGON (CONT)

lichens
lignin (2)
limulus (4)
lipopolysaccharide (2)
lobar
lobar pneumonia
lumen
lymphocyte
lymphocytes (4)
lysogeny
lysosomal
lytic
macromolecules
macronucleus
macrophages
macrotermes
mandibles (2)
margulis
mastodons
matrix
membrane (6)
membranes
membranous
meningitis (3)
meningococcal
meningococci (3)
meningococcus
metabolic
metamorphosing
metazoan
metazoans (3)
meteorites
methane (2)
methyl
microbe (2)
microbes (5)
microbestiary
microbial (4)
microfloras
micronuclei
microorganism
microorganisms (2)
microtubules (2)
mitochondria (18)
mitosis (2)
molecular (2)
molecule (3)
molecules (2)
morphogenesis (4)
motile (2)
multiple sclerosis
mutants
mycetocytes (2)
mycetomes
myopia
myxotricha (4)
myxotricha paradoxa
nanosecond's
nematodes
nephritis
neurons (5)
neuropathology
neurophysiologic
nitrobenzene
nitrogen
nodules
nonentomologists
nucleated (2)
nuclei (8)
nucleic (5)
nucleotides
nucleus
nudibranchs
oceanographic (2)
olfactory (11)
oncology
ordinates
organelle
organelles (14)
organism (12)
organisms (6)
osmic frequencies
oxidative (3)
oxygenation
ozone
p-chlorophenol
Paleozoic
paradigm
paradoxa (2)
paramecium bursaria
parasitic
parenchyma
Parkinsonism
pathogenicity (2)
pathogens
peptides
pertussis
phage
phages
phagocytic (2)
pharmaceutical
phenol
phenolic
phenotype

LIST OF JARGON (CONT)

phenylethyl alcohol
pheromone
pheromones (9)
photo-dissociation
photolysis
photons (2)
photosynthesis (6)
photosynthetic (4)
pili
pismire
plankton (2)
polarized
poliomyelitis (2)
polymer
polymers (3)
prebiotic
primates (2)
proboscis
progeny (3)
prokaryocytes
prokaryotes
prokaryotic (4)
prostaglandin
protozoan (6)
pulmonary
pyrogen (2)
quantum mechanics
quarantine
radioactive
reagent
refractile
replicate
replicating
replication (2)
respiratory
respiring
reticuloendothelial
rheumatic
rheumatoid
rheumatoid arthritis
rhinopharynx
rhizobia
rhizobial (2)
ribosomes (4)
RNA (3)
rotifers
schizophrenia (2)
schizophrenic
schizophrenics
sclerosis
semipermeability
septicemias
sessile
sickle-cell
siphons
slime
sonar
spectrograph
sperm
Sphex
spirochete (2)
spirochetes (7)
staphylococci
streptococci (2)
streptococcal
streptomycin
subcolonies
sulfonamides
superorganism (2)
superorganisms
swin-bladders
symbiont
symbionts (5)
symbiopholus
symbiosis (8)
symbiotic (7)
syncytium (2)
syphilis
taxonomy
templates
tentacles
terrestrial
thermodynamic
thermodynamically
thermodynamics
toxin
toxins
trans-3-methyl-hexanoic acid
tropism
tubercle
tuberculosis (2)
tubules
typhoid fever
ultrasound
urchin
vascular
vibrios
virus
viruses (2)
viscera

LIST OF JARGON (CONT)

visceral
voles

APPENDIX E

LIST OF NOMINALIZATIONS

In the following alphabetized list, each word appears only once in The Lives of a Cell, unless otherwise noted.

absence
abnormalities
abstraction (3)
abundance (3)
acceptance (2)
accommodation (2)
accuracy
achievement (2)
acknowledgment
acquaintance
action
actions
activity (4)
adaptation
adoption
addiction
admonition
advances
advertisement
affection
aggregation (3)
agreement (2)
agreements
aggression (3)
allusions
alternation
amazement
ambiguity
analysis
announcement (2)
appearance (3)
application
applications (2)
apprehension
approachable
argument
arrangement (12)
arrangements (4)
arrogance
askewness
assemblage
assessment
associations
assumption (2)
assumptions
astonishment (4)
attachment (3)
awareness (2)
behavior (4)
betterment
calculation (2)
capability
capacity
celebration (3)
certainty (3)
cessation
chanciness
circumnavigation
classification
collaboration
collaborations
collisions
combination (2)
combinations
commitment
communication (9)
completion
compulsion (2)
concentrations (2)
configuration (2)
configurations (3)
confirmation (2)
confoundment
confusion (2)
confusions
connectedness

LIST OF NOMINALIZATIONS (CONT)

connection (3)
connections (5)
connotations
consciousness (2)
construction (5)
consumption
convergence
conversation
conversion
cultivation
curiosity
dazzlement
death
decisions
defense
delusions
demonstration
depletion
depolarization
derangement
destruction (4)
detachment
detection
detestation
development (3)
developments
differentiation
digestion
direction (2)
directions (2)
disagreement
discernment
discoveries
discrimination
discussion
disintegration (2)
disorganization
distortion
distribution
diversity
dominance
economy
education
effectiveness
efficiency
embarrassment (4)
elaboration (2)
emergence (4)
encouragement
encroachment
endowment
engulfment
enhancement
enlightenment
enormity
enrichment
enthusiasm
equity
establishment
establishments
evolution (2)
examination (3)
excitement (2)
exercise
exhalation (2)
existence (7)
expansion (2)
expenditures
experiment (2)
explanation (5)
explanations
exploration (3)
explosion (3)
explosions
exposure
extension
exuberance
fallibility
fluctuation
formation (4)
fragility
function (3)
functions (2)
fusion (4)
generalizable
generation
governance (2)
governments
guidance
hospitalization (3)
humiliation
identification
illicitation
illusion (2)
illustration (2)
illustrations
imagination (3)
imaginations
imbalance
immensity

LIST OF NOMINALIZATIONS (CONT)

immunization
implications
importance
impossibility
imprecision
impression
improbability (2)
improvement (3)
incantation
inclination
incongruity
indelicacy
infiltration
inflammation (2)
influence (2)
information (12)
inheritance
injection (2)
installation
installations
instructions (8)
insults
intelligence
intensity
intention (2)
intentions
interactions (2)
interconnections
intervention (2)
intrusion
invention (5)
inventions
inventiveness
investments
invitations (2)
involvement (4)
irradiation
isolation (3)
jubilation
kinship
knowledge
location (2)
magnificence
magnification
maintenance
management (4)
manipulations
manifestation
manifestations
measurement
migrations (3)
misinterpretation
misinterpretations
mixture
modulation (2)
moroseness
movement (3)
movements
navigation
negotiations
nonexistence
notation
nourishment
obligation
observance
observation (3)
obsession
occupation
occupations
olfaction
operation (5)
ordinariness
organization (6)
ornamentations
oversimplification
ownership
painlessness
pathogenicity (2)
penetration
perceptions
perfection (3)
permanence
photodissociation
population (2)
populations
possession (2)
possibility
possibilities
precision
prediction
predictions
preoccupation
preparations (2)
preservation (2)
prescriptions
presumption
prevention (2)
probability (2)
production (5)
profit
proliferation
promotions
pronouncements
proposition

LIST OF NOMINALIZATIONS (CONT)

protection (2)
provision
publication
purchase
quietude
randomness
reaction
reactions
realization (4)
rearrangement
reassurance (2)
recapitulation
recognition
recommendation
recruitment
reductionism
regeneration
regulation (3)
rehabilitation
relation (2)
relations
relationship
reorganization
requirements (2)
repellance
replacement (4)
replication (2)
reproduction
resemblance (3)
resemblances
reservation
reservations
revisions
rightness
satisfaction (2)
selection (2)
semipermeability
sensation
separateness (3)
separation
significance
simulation
slippage
sophistication
specialization
speciation (3)
specificity (2)
speculation
sponsorship
stimulation
strangeness (2)
strengthening
suggestion (4)
suggestions
survival
sustenance (2)
symbolism (2)
temptation (2)
training
tranquility
transaction
transactions
transformation (2)
transformations (3)
transplantations
treatment (8)
uncertainty
understanding
uniformity
union
unlikelihood
unpredictability (2)
vanishing
variation (2)
variations (2)
ventilation
vibrations (2)
vulnerability
withdrawal
wonderment (2)

VITA V

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