INTRODUCTION

Disseminating new theories, ideas and the results of research has always been an integral part of scientific practice. The need to share findings and scientific knowledge with the scientific community where it can become the common property of those engaged in the research endeavor is part of this ethos. According to classical sociology of science, one of the most important values to scientists is Merton's norm of communism, which prescribes the full and open communication of scientific discovery. "Newton's remark--- 'If I have seen farther it is by standing on the shoulders of giants'---expresses at once a sense of indebtedness to the common heritage and a recognition of the essentially cooperative and selectively cumulative quality of scientific achievement (Merton, 1973, p. 275). Scholarly communication has traditionally occurred both through formal publication, including scholarly journals and monographs, and through informal exchanges at conferences, interpersonal contacts, letters, and the exchange of articles or preprints. No matter what form this communication takes, science is particularly dependent on dialogue and feedback in order to move forward.

Even in the dawning age of electronic communication, the most important publication medium for scientists remains the scholarly peer-reviewed journal. Publication in a peer-reviewed journal confers validation on findings, prestige to the authors, and provides an important basis for recognition in the awarding of grants and tenure for scholars (Ziman, 1968; Merton, 1973). There are some interesting new developments in scientific communication patterns, however, that are forcing all parties interested in the scholarly journal to reassess the status quo. With the increased usage of personal computers and the growth of computer networks, in particular, the World Wide Web, electronic communication is opening up new possibilities for scientists to exchange information quickly and efficiently. Computer-to-computer communication involving e-mail, and the transmission of files and data have speeded up the exchange. Scientists have begun to develop electronic "collaboratories" where they share data, instrumentation and computational resources at a distance. "In the digital world, information conveyance devices that provide identification, transmission, and storage functions are no longer discrete physical entities" (Crawford, Hurd, and Weller, 1996, p. 6). They exist on

networks that are independent of place, concrete walls or hard copy publications. For communities of scientists that prefer speed in communicating results, e-mail and the Internet have begun to change traditional modes of disseminating results. Physicists, in particular, have led the way in electronic networking.

One of the most interesting innovations in the dissemination of scientific knowledge is the experimental electronic preprint archives set up in 1991 by Paul Ginsparg, a physics research staff member at Los Alamos National Laboratory in New Mexico. Physicists from all fields can post copies of papers that they intend to submit for formal review to a journal. Upon receipt they are tagged and archived, unvetted, yet accessible within days to anyone with a computer and a connection to the World Wide Web.

The main question to be investigated in this work concerns the phenomenon of the e-print archives, especially their utility and usage among different scientific communities. Their growing popularity among physicists, for example, stands in stark contrast to the reception of e-prints in the fields of chemistry and biology. Currently, there are several e-print archives for physicists, mathematicians and astronomers on the web, but none for chemists.

In order to make the project manageable, the focus in this thesis is on physicists and chemists working at a large research institution. The reason for selecting physicists is that they are the most active users of e-print archives. Chemists are a good choice for comparison because certain groups of chemists are similar to physicists in their fields of study, specifically, physical chemists and nuclear chemists. If technical content plays a role in explaining why one group of scientists embraces the medium while another community rejects or simply ignores the archives, then studying the experiences of practitioners in physical chemistry and chemical physics may help elucidate the matter. There are no e-print archives for chemists in use today. The difference in their endorsements, through use of e-print archives, may be taken as evidence that physicists and chemists differ in their attitudes toward electronic pre-publication. This case study will involve twelve scientists at the University of Maryland (UMD) in both the Physics and Chemistry Departments. Before beginning, I applied and received an approval for research involving human subjects from the Institutional Review Board of the Virginia Polytechnic Institute and State University. Dr. Hurd sent me an IRB Exemption approval-IRB #98-282 in

November, 1998. I also received permission from all twelve interviewees to use their real name in this thesis.

This discussion of electronic preprints will necessarily involve issues surrounding scientific publication to include peer review, priority, fear of being anticipated, rewards, prestige, scientific publishers, and the structure of research groups that produce manuscripts. Seeking an explanation for the variety of viewpoints concerning the usefulness of the e-print archives will involve focused interviews, surveying the literature, and studying the attitudes of the two scientific societies that publish many of the most important scholarly journals in chemistry and physics. Specifically I refer to the American Physical Society (APS) and the American Chemical Society (ACS). A selective snapshot of two departments at UMD cannot tell us whether all physicists and all chemists are similar to those studied, but it can point to some general theories and explanation for current practices. As Yin (1989, p. 21) explains it, "Case studies are generalizable to theoretical propositions, not to populations or universes."

The essence of this case study is an attempt to illuminate which scientists, in both departments, are using the e-print archives and why this is the case. The study looks at several potential explanations. One explanation stems from the researcher's technical expertise with information technologies. Most physicists are comfortable with using computers, e-mail, and computer networks to do their work, and they share common software that may facilitate usage of the servers. In fact, it was physicists who created the networks that marked the beginning of the Internet. The U.S. Defense Department's Advanced Projects Research Administration Network (ARPANET) that formed the backbone of the Internet was manned and operated by physicists. Physicists have incorporated the use of this huge network of connected computers, that we now call the Internet, into their work culture. Mentors and peers help socialize young scientists into the accepted ways and preferred tools for communicating in a discipline. In this case, work-styles and habits of communication of the early developers of networked communication may have served to make the transition to the electronic environment more acceptable to some physicists than to other scientists.

Social relations and group identity also help explain communication patterns. I rely heavily on Mertonian sociology of science and the structural approach in this discussion about

scientist's choices and preferences for disseminating their research. This is not meant to ignore the valuable insights of social constructivism and the sociology of scientific knowledge. As Chubin (1976, p. 449) points out: "That intellectual, cognitive, or problem content can generate different kinds of structure has eluded or at best been underemphasized by sociologists of science." This discussion looks at subject content to see if it might have some explanatory power over the use of e-print archives. However, the focus on subject content is limited to the researcher's own perception of how their work should be catalogued as they assign a subject classification to their manuscripts in submitting to the archives. Similarly, the choice of the most appropriate journal to which to send a manuscript is related to the researchers own perception of the best match between their subject content and the most interested community of readers. Structural functionalism provides a satisfactory analytical framework for the problem at hand, with my focus on community norms and structure.

Another explanation may be that in some communities, the practice of informal review predates the electronic information age. Informal review may thrive where closely knit groups of researchers can easily sift through unrefereed material and distinguish what findings are on target. Historical patterns of sharing paper drafts or preprints before the advent of electronic file exchange may reveal entrenched attitudes that carry over to the digital environment. The literature on the structure of research groups that merge into scientific specialties reviewed by Chubin (1975; 1976) reveals a variety of relationships, collaborations, and apprenticeships that coalesce around functional units of varying size. The relationship of "trusted assessorship" captures the practice of sharing manuscripts with a few trusted colleagues in the preliminary stages of preparing reports before they are ready for formal peer review. Presumably, the decision to send a manuscript to the electronic e-print servers assumes that the author is sufficiently confident that the work is ready for world-wide dissemination.

The control wielded by scientific publishers must also be considered. How scientists choose to disseminate their research is determined in part by the editorial policies of the journals to which they submit their manuscripts. Related to this is the individual scientist's understanding and perception of how priority will be established when submitting a manuscript. Traditionally, priority conflicts are resolved by examining the receipt date stamped on the manuscript by the

publisher. Some subfields of physicists, however, consider that submission to e-print archives is sufficient to claim priority to an idea.

Finally, economic factors may have an influence on attitudes about the e-print archives. For example, concern about getting crucial grants to sustain the research endeavor may have an impact on patterns of disseminating e-prints. Also, if a scientist's work has the potential to be patented, then preliminary electronic publication may be completely out of the question due to intellectual property concerns. These possible explanations are not mutually exclusive. Moreover, economic, historical, and social factors will likely interact with perceived issues of technical content. It can be expected that a complex and interrelated set of explanations will be needed to understand the way in which the innovative e-print archives are perceived and received by different communities of scientists.

The organization of this thesis is the following: Chapter 1 defines and explains the space where preprints are located within the production and creation of scientific reports. To fully understand whether an electronic preprint might ever supplant the formal published article, the historical development of the scientific peer-reviewed journal into its' current position of primacy for reporting research findings, is presented. There follows a review of some of the literature on informal communication and group identity.

Chapter 2 covers the current innovation of e-print exchanges afforded by the Los Alamos e-print archives. This early dissemination of manuscripts might threaten the revenue stream of scientific publishers who are concerned about retaining control over copyright. Quality control and filtering provided by peer review is discussed. Finally, the stance of the APS and the ACS to the e-print archives is compared.

Chapters 3 and 4 provide a synopsis of the twelve interviews with physicists and chemists. These chapters conclude with a brief overview of the issues raised. Chapter 5 analyzes and discusses the hypotheses set out in the introduction. Preliminary findings based on the responses of the twelve interviewees are presented with mention of possible fruitful areas for further investigation.

Chapter 1-Historical Background

Scientific Communication and Definitions

At the outset it is important to clarify what preprints are and how their usage fits within the full scheme of scholarly publishing. Preprints are typically produced near the front-end of the dissemination process, that is to say, in the pre-publication phase of publishing scientific results. Part of the informal transfer of information between scientists, preprints can be lumped with conversations, letters, reports, seminar presentations and electronic mail. What these media for the dissemination of scientific work all have in common is the provision of a space for speculating and testing ideas. "These informal channels of communication obviously play a vital part in the research enterprise. They are the means by which speculative ideas, technical wheezes and other 'unpublishable' items of information diffuse through the scientific community. They are often the means by which significant new developments come to the knowledge of active research workers, long before they can be formally published" (Ziman, 1984, p. 67).

Garvey, Lin, Nelson, and Tomita (1979) of the Center for Research in Scientific Communication at Johns Hopkins worked on a study of information-exchange patterns among 12,000 scientists and engineers in a sample of nine physical, social and engineering sciences. They studied the role of the national meeting in facilitating communication among scientists, the structure and function of the formal and informal networks between researchers, and the relationship between the various media for disseminating research, including technical reports, progress reports, preprints, and journals. They developed a schematic model of the information-flow process that is simplified in the following diagram (Garvey et al. 1979, p. 169):

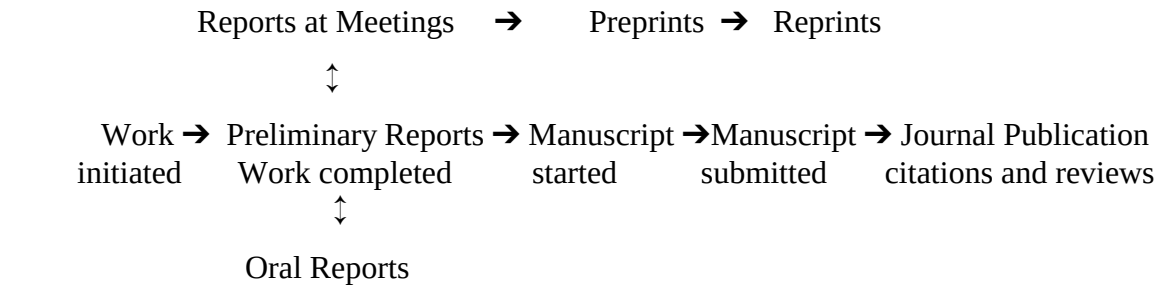

Figure 1-The Information Flow Process

This model tracks the information flow from its rough and private stage through to its polished, public form. After research is conceptualized and begun, communication branches out to include close colleagues. Next, preliminary findings might be shared in colloquia and gatherings among peers. The work might be discussed as an interim report or in a poster session at a meeting or conference. When the process of writing up the results in a manuscript are completed, scientists sometimes choose to circulate their papers, otherwise labeled as preprints, to interested peers in their communities. Gradually, the information flow broadens out to include peers at other institutions and editors of scientific journals. Finally the communication reaches a general scientific audience in a formal garb as an article in a peer reviewed archival journal. Everything preceding actual publication in a scholarly journal is considered informal communication under this schema. Preprints fall right in the middle of this information flow. They are preceded by the more casual information exchanges that may occur as scientists conceptualize their experimental programme with colleagues and work through the research. At the point when a manuscript has been written up in a complete and defensible format, a scientist may choose to send it out as a preprint before submitting it for formal review or simultaneously with the process of submission to a publisher.

According to Youngen (1998, p. 44), preprints fall into three different categories:

> 1) manuscripts that are intended for publication but are being circulated among peers for comment prior to being submitted for publication.
> 2) manuscripts that have been submitted for publication but for which the decision to publish has not been made;
> 3) manuscripts that have been reviewed and accepted for publication;

Motivations vary for choosing to distribute preprints. One motivation, reflected in the first category, would be a scholar's felt need to get some feedback or guidance from colleagues before sending off the work for formal peer review. Garvey (1979) described preprints as a "series of soundings" putting forth information, and testing reactions leading to modifications and editing. This category is close to the notion of a preprint as a paper in draft format, acknowledging the possible need for stylistic or substantive changes. The presumable motive to disseminate both of the last two types of preprints is the desire to reduce the lag time of waiting for a paper to appear in print. Even after a paper has gone through the time consuming work of peer review, it sometimes takes months to appear in an archival journal. Hagstrom (1970, p.85) felt that a high rate of preprint exchanges reflected a kind of failure of the journal system for disseminating information. If scholars felt the need to disseminate papers themselves, then the journal system was failing to meet all the needs of the researchers.

The Role and Function of Preprints

In order to understand the role that preprints play within the information-flow model we need to understand not only where and when preprints are used, but how their usage relates to other media in the process. As pointed out by many scholars, (Garvey, 1979; Hagstrom, 1965; Ziman, 1984) the scientific communication structure may be understood as a social system that is complex, rigorously controlled, and resistant to change. Each decision about what media to choose for communicating and when to use it can be traced to a complex series of interrelated factors. If one vehicle fails to satisfy the information needs of scientists, a new medium might

take shape. Any change in one part of the structure will likely have an effect on other components of the system.

The act of putting research into a communicable form and getting the work disseminated is crucial to the scientific endeavor. Because science is a collective activity that is achieved through a slow process of building on the findings of others, such communication holds it all together. As Ziman says, "From this point of view, the communication system is the essential structural component of the scientific community" (1984, pp. 107-108). Because people are involved, the communication system is necessarily messy. It is constantly shifting with the changing attitudes and circumstances of the scientists within the system. It is intertwined with economic, social, cultural, psychological, and historical factors. The communication system involves the use of different media, using a broad variety of formats that have taken shape gradually over time. This system reflects both the needs and values of the communicators and those of the recipients of the communication stream. At any given time, the methods and shape of communication reflect the influence and social control of colleagues, institutions, and cultural traditions (Merton, 1973; Hagstrom, 1965; Bazerman; 1988).

Historical Development of the Scientific Journal

In order to understand the practice of e-print pre-publication, therefore, we must fully understand the role of the formal journal article. The position of primacy of the peer reviewed journal as the most important vehicle for reporting scientific findings has held for centuries. This system of scholarly communication, however, took hundreds of years to develop. A look at this development will provide an historical context for understanding today's scientific communication patterns.

Throughout history, natural philosophers and scientists have confronted a recurring tension between secrecy and openness. A desire to remain secretive about discoveries has often co-existed with an urge to reveal findings. The earliest investigators, searching for understanding of the natural world, carefully recorded results of their observations. From ancient Greece, Galen's manuscripts and letters detailing the results of careful dissections reveal the basic human need to communicate discoveries with others. Extant astronomical yearbooks and carefully hand-recorded details of comets and planetary movements like the Cometicae Observationes of

the seventeenth century bear testament to the continuing urge to document and disseminate observations. However, societal pressures from state and religious authorities have repeatedly threatened open-ended commentary and investigation as illustrated by incidents like the Catholic Church's condemnation of Galileo's writings in 1633 (Ronan, 1974).

Secrecy surrounding the communication of findings, sometimes forced upon scientists under the threat of punishment and excommunication by the Church, was also motivated by other factors. Galileo, for example, sent a coded message to the Tuscan ambassador in Prague that read: "SMAISMRMILMEPOETALEUMIBUNENUGTTAURIAS." Galileo had observed the rings of Saturn and interpreted the image he saw as that of three co-axial spheres. This Latin anagram states "I have observed the highest planet (Saturn) in triplet form" (Hagstrom, 1965, p. 92). Unwilling to share such questionable findings prematurely, Galileo wanted, nevertheless, to make sure he would be credited with priority in this discovery. The importance of being first to report new phenomena gradually became a paramount motive in encouraging the reporting of findings. The act of establishing priority through publication, and the coupling of publication with recognition and rewards emerged slowly with the first scientific journals. The formal scientific journal article as a form of communication has become institutionalized, but it was a process that took many years.

The first scientific journal emerged from the enthusiasm and excitement generated by a group of natural philosophers in seventeenth century Europe who had the leisure and curiosity to develop the experimental method in scientific investigations. The new technology of the printing press and movable type developed during the late fifteenth century enabled investigators to communicate new discoveries with others far and wide (Eisenstein, 1979). The ability to publish, combined with a gradually improving system for distributing printed matter, contributed to the development of science. The invention of printing was necessary, but not sufficient to create the conditions for the emergence of a form of regularized reporting about natural science (Kronick, 1976). The intellectual movement of the Enlightenment provided the background for the emergence of scholars like Bacon who encouraged the experimental method. As he described it in the Novum Organum, shaking up and vexing nature through the use of experiments and observation was the best way to understand the natural world. "And just as in

ordinary life the true personality of a person and his hidden thoughts and motives show themselves more clearly when he is under stress than at other times, so things in Nature that are hidden reveal themselves more readily under the vexations of art than when they follow their own course" (Bacon, 1994, p. 108).

Early Scientific Journals

Groups of investigators joined forces to form scientific societies in many capitals of Europe. In England, the meetings for gentlemen of the Royal Society included public experiments whose results were spread through letters to the continent. The primary medium available to scholars for the communication of ideas before the appearance of the periodical was personal correspondence (Kronick, 1976, p. 56). The growth of a reliable postal system and the importance of this active correspondence of erudite letters prompted the beginnings of the learned journal. According to Zuckerman and Merton, these scientific societies "...provided the structure of authority which transformed the mere *printing* of scientific work into its *publication*" (1973, p. 462). The transition from the act of merely testifying to or witnessing an experiment to the evaluation of the validity and reliability of an experiment marked the important burgeoning role of societies as legitimizers of scientific knowledge. *The Philosophical Transactions of the Royal Society*, edited by Henry Oldenbourg, was authorized by the Society in 1664 to be "... printed the first Monday of every month, if he have sufficient matter for it; and that the tract be licensed under the charter by the Council of the Society, being first reviewed by some of the members of the same" (Zuckerman and Merton, 1973, p. 463). The concepts of the need to authenticate results, to provide review by a group of peers, and to establish recognition for arriving first in scientific discoveries began to be identified with the role of the scientific journal. The importance of reviewing and editing took shape gradually in early scientific journals like the *Journal des Scavans* and the *Transactions*. "The Society was also beginning to distinguish between evaluated and unevaluated work which came to its notice. On occasion this involved the policy of 'sit penes authorem fides (let the author take responsibility for it): We only set it downe, as it was related to us, without putting any great weight upon it" (Zuckerman and Merton, 1973, p. 468). This kind of statement is remarkably close to the caveat placed upon the electronic preprint servers today.

These early letters and journals were a form of communication closer in resemblance to a preprint than to formal publication of today. “The correspondence of the scholars of this period...served as a place where new ideas could be developed and critically examined before they were committed to the record, which in the days before the periodical was either the printed book or pamphlet, and it continued to play this role throughout the 18th century “ (Kronich, 1976, p. 56). Publication was not considered definitive when it appeared in some of the early journals. Oldenbourg extracted portions from his correspondence and edited the reports of results and findings. “The papers delivered before the Royal Society and the experiments performed there were rendered in Oldenbourg’s own words. For example, Leeuwenhoek’s letters which began to appear in the *Transactions* under Oldenbourg’s editorship were presented in abridged form, and the fact that Leeuwenhoek himself did not consider this a form of final publication is attested to by the fact that he had them printed in book form in his own lifetime in both Dutch and Latin” (Kronich, 1976, p. 80).

One of Oldenbourg’s first challenges was to get enough interesting material to sustain the effort of publication. As Zuckerman and Merton (1973) point out, Oldenbourg developed several institutional devices to induce scientists to participate in this new venture. He offered to establish their priority over new knowledge by dating the receipt of communications. He promised to register intellectual property rights, and he offered speedy printing of findings. “Printing thus provided a technological basis for the emergence of that component of the ethos of science which has been described as ‘communism’: the norm which prescribes the open communication of findings to other scientists and correlatively proscribing secrecy” (p. 464). Right from the start, however, the tension between secrecy and sharing results was apparent. Boyle complained that his work was often plagiarized in circulated but unpublished manuscripts. He called it “philosophicall robbery” (p. 465).

The *Transactions* started out as correspondence between scientists, and gradually took the shape of a scientific journal with articles grouped together to describe various observations and experiments. The scientific journal has had to play a double role, that of being at the same time a vehicle for and a repository of information (Kronick, 1976). The goal of disseminating and communicating was intertwined with the goal of providing a record so the priority disputes could

be resolved and information could take on some notion of permanence.

The Modern Scientific Journal

The modern journal format began to take shape out of this need for a vehicle to report brief communications of particular experiments. The slow development of the experimental report has been well documented by Bazerman (1988).[1] The experimental approach favored reports of small, discrete units of information, rather than in-depth development of broad topics. From individual observations and reports, the polemical nature of claims and counterclaims took shape. "The journal facilitated not only criticism, but the public role of the critic. Just as correspondence networks had served to increase the amount and immediacy of criticism, the journal made the critical activity public" (Bazerman, 1988, p. 135). Persuasion became paramount in winning scientific agreement on what facts were valid. Over time, the audience narrowed to exclude the general, educated, public and include those who were most intimately involved in the proceedings. Gradually the act of publishing in the *Transactions* became coupled with belonging to a new type of select group. "Presenting work before the Royal Society and being mentioned in the pages of the *Transactions* identified one as a natural philosopher. The success and prestige gained by the journal then accrued to whoever published therein. Perhaps more importantly, this prestige lent legitimacy to the work itself (Bazerman, 1988, p. 138). According to this perspective, only those who were engaged in similar pursuits could fully understand the details of conducting research and appreciate the theoretical background underlying the reports. Competent appraisal could only come from those who could replicate and validate results. The acceptance of peer review depended on the competence and authority of those performing the review.

The emergence of the carefully codified scientific report gradually moved from individual claims to a sensibility on the part of the investigator of the impact of and indebtedness to his predecessors. Researchers began to acknowledge the interconnected nature of their findings within the broader community of scientists. Today we look upon science as a field that builds upon and extends knowledge from previous work. But recognition of the need to acknowledge

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[1]For a more complete discussion of the development of the experimental report within the Royal Society, see Bazerman, 1988, chapter 5.

previous findings only emerged gradually into the conscious habits of scientists. Citations did not appear regularly until the 19th century. "Citations began only as a recognition of debt, but developed into a close interlinking of the current work with the on-going research and theory which formed a codified network of the literature" (Bazerman, 1988, p. 139). The current shape of the scientific journal took hundreds of years to evolve, changing with the social needs of the contributors, readers and editors.

Function of the Journal Literature

By the late twentieth century, scientists have come to rely on the journal literature to fulfill several crucial functions. The cumulative body of published reports and research findings builds a corpus of validated knowledge that represents a consensus among practitioners (Ziman, 1984). As an archive it represents the collected wisdom of the ages. Manuscripts are offered as "gifts" or contributions to the community with the hope that recognition will follow (Hagstrom, 1965, p. 12). Scientific papers are submitted to peer review, and, if accepted for publication, garner prestige and recognition to their authors. Publishing articles in a prestigious journal in a scientist's field is one of the most important ways that young scientists can distinguish themselves. Publication in a peer-reviewed journal is, by tradition, the only accepted way to establish priority for a discovery. The journal is the main vehicle for communicating results.

Journal Peer Review

The importance of peer review to this process can not be understated. Peer review represents a kind of Maginot Line between prepublication media and formal publication. Whatever its faults and shortcomings, peer review has served scientific communities, as a generally recognized and accepted mechanism for allocating resources, prioritizing research activities, rewarding promising research, and advancing scientific knowledge. Ironically, the culture of science promotes the open sharing of ideas within the community, while closely guarding the right of the community to self-regulation and the autonomy of accepting or rejecting claims in a secretive process. Chubin and Hackett (1990, p. 94), for example, have opened up the black box of peer review, and revealed some of its internal contradictions in the process:

> This is the paradox of journal peer review: the open sharing of knowledge through publication is preceded by secret deliberations among a few scientists acting with calculatedly restricted information, vague and unenforceable guidelines, and little accountability to authors.

For all its faults, journal peer review is the only means currently available to make qualitative assessments about whether the work is a significant and important contribution to the research question. With the overwhelming amount of information inundating most researchers today, the value of screening and filtering cannot be underestimated.

Scientific Norms and Communication

In 1942, when Merton suggested his set of norms that govern the behavior of scientists, he was describing behavior that had developed gradually through time. Those norms are closely interrelated with the communication structure of scientists as well. Originality, scepticism, and universalism each come under consideration during the act of peer review. Reviewers and editors must decide whether the scientific work is new. They must take a skeptical stance to find possible factual errors and problems in the argument. Reviewers are expected to be impartial and to avoid giving more weight to work that is done by well-known scientists. Communalism is important to the communication process because scientific discoveries are to be regarded as part of public knowledge, freely open to all. Secrecy is antithetical to publication. In addition, because original work is highly rewarded, competition in establishing priority has a big impact on the process of disseminating results. This important issue of how scientists claim priority is also crucial to our understanding of the role of prepublication media, especially that of preprints.

Rush to Publication

Because preprints provide a means to speed up dissemination of information, they can be used to announce a research finding or to stake a claim on a given question. The fear of being anticipated when working in a "hot" field has led some scholars to circumvent the established procedures of waiting for formal publication. An editor of *Physical Review Letters* reveals some of the frustration surrounding this practice: "...an author who uses the 'Letters' merely to announce a later paper and whose Letter is incomprehensible by itself;...an author who tries to sneak a Letter in to 'scoop' a competitor who has already submitted a full article..." (Hagstrom,

1965, p. 94). The desire to arrive first at a discovery may force scientists to rush their work into abstracts or letter journals before an idea is completely developed. The use of preprints may be a kind of sneaky way to establish priority by circumventing the more formal authentication process of submission to a formal publisher. Fear of being anticipated can lead to secretive behavior, a form of deviance among scientists (Hagstrom, 1965). Add to this the fear of losing grant support and the rush to beat the competition becomes more severe. "The dilemma between recognition of rights of priority and the maintenance of open channels of communication can be softened in various ways, but it cannot be completely resolved" (Hagstrom, 1965, p. 98).

Literature Review on Preprint Exchanges

There have been several studies of communication patterns of scientists that have highlighted the usage of preprints. Locating the cutting edge work of science in the informal domain, Garvey et.al. (1979, p.211) found that physical scientists distributed preprints more than social scientists. Researchers were more likely to send out preprints if they had worked in their areas of speciality longer, devoted more time to basic research, conducted their work more expeditiously, and made more prepublication reports of their work. It will be interesting to see if any of these factors hold true among scientists today who use the e-print servers.

Looking at competition and teamwork among scientists, Hagstrom (1970) studied scientist' attitudes about sharing information before formal publication. He surveyed research scientists on productivity and publication patterns. In focusing on work habits and communication practices of scientists from four different disciplines, he found differences among chemists, mathematicians, biologists and physicists in their use of abstracts, reprints, preprints, and review articles. He looked at forty-six specialties among these disciplines and found a high rate of preprint distributions in those fields with high rates of discovery, where work becomes obsolete rapidly, and where journal publication lags have a negative impact on the conduct of research (Hagstrom, 1970, p.100).

Traditionally, many scientists have adopted the practice of sending out copies of their papers to colleagues at the point when they were ready to submit a manuscript for publication. Sent through the mail to those working within the same related areas, this practice allowed what has been described as "the invisible college"of researchers to keep current with new

developments, without having to wait for the published formal journal (Price 1963, Crane 1972). Ziman (1984, p.99), explained this notion of an invisible college by comparing it to Ludwig Fleck's "thought collective." The members would share an intellectual specialty, establish communication links, share a common tradition or preference for techniques of investigation, accept certain empirical facts and conceptual schemes---in essence, they would share a style of thinking. The utility of exchanging preprints, working in this kind of community, would be enhanced because of these shared meanings.

Chubin (1975;1976;1985) has provided an overview of the 'primary group'segment of the sociology of science literature describing how researchers cohere into working relationships and coalesce around scientific specialties that have both a social and intellectual dimension. The notion of specialty or subfield includes a myriad of possible functional units like work groups, clusters, networks, invisible colleges, and social circles. "These units are indeed microenvironments or contexts for doing research and communicating about it. In other words, the contexts constrain relations among scientists" (Chubin, 1976. p. 455). Chubin goes on to point out how innovations can emerge from scientists who come from the margins of a specialty. It is interesting to speculate whether the e-print archives might provide an area where exposure to new work is enhanced through its use by foreign scientists and younger marginalized scientists.

Ziman (1968, p. 110), who was a physicist before beginning to write about science, took a jaundiced view of the practice of sending out preprints. "...a preprint is a clumsy, bulky, semi-legible document, being a duplicated version of a paper submitted for publication but not yet accepted and printed...Preprints are unpleasant to read (especially if the mathematics is clumsily typed or written on the stencil) and most of them that one gets are quite irrelevant to one's interests, being distributed according to some vague list..." Efforts to formalize the practice of distributing paper preprints were condemned by Ziman because the papers might be mistaken for the formal official literature. "The fact is that the publication of scientific papers is by no means unconstrained. An article in a reputable journal does not merely represent the opinions of its author; it bears the *imprimatur* of scientific authenticity, as given to it by the editor and the referees whom he may have consulted" (Ziman, 1968, p. 111).

Today the technological situation has changed dramatically. Preprints are no longer

bulky, messy or cumbersome. Electronic dissemination has created opportunities to share preprints instantaneously with the entire world. Self-publication in this environment is efficient and highly readable. The format resembles the look and feel of traditional journals with a familiar page layout and neat typesetting. The main factor that still sets the formal literature apart from the informal in this situation is the act of peer review. In fact, the distribution of electronic preprints has upset the delicate balance between scientists and their publishers. The next chapter will cover the development of this new situation and its implications for scientific publishers.