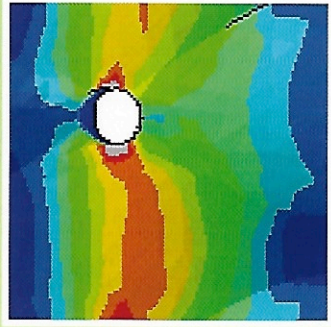


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Journal of Undergraduate Research



Volume Ten
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University of Rochester

The *Journal of Undergraduate Research (jur)* is dedicated to providing the student body with intellectual perspectives from various academic disciplines. *jur* serves as a forum for the presentation of original research thereby encouraging the pursuit of significant scholarly endeavors.

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From the Editors

How, and in what manner, should undergraduates engage in research?

When we asked our readers this question in our letter from the editors for the Fall 2011 issue of *Journal of Undergraduate Research*, we did not expect to receive such a variety of responses in our submissions. Our journal has always been committed to seeking and publishing work from all fields of study, so the diversity in topics in our Spring 2012 issue should come as no surprise. Yet in keeping with the increased involvement of undergraduates in research-driven projects, this issue encompasses a new diversity in our authors' research methods and motivations. In these pages our readers will experience discoveries that came about through cultural immersion, laboratory experimentation, and computer simulation modeling. What is most striking about the collection of topics presented here is the degree to which technology has played a role in reaching new conclusions and going beyond the boundaries of past research. Whether technology brings about increased cultural awareness and ease of travel, more precise scientific techniques, or the ability to mathematically reconstruct ancient architecture, its role in the undergraduate research experience cannot be denied. We can only hope that next year's volumes will continue the trends we have started this year in broadening our readers' view of what constitutes research.

Sincerely,

Sthuthi David and Cameron LaPoint

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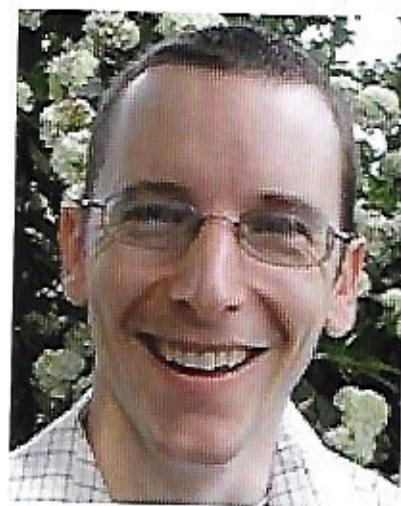
About the Journal

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Professor Interview

STUART V. JORDAN, PH.D.

Assistant Professor of Political Science



jur: Could you tell us a little about your educational and professional background?

Jordan: I went to Dartmouth College and graduated in 1998, I worked for about four years as a social worker in a non profit that provided housing for homeless families, and then I went back to school to get a masters in public policy. While I was getting my masters degree, I was exposed to some research in political science, fell in love with it and decided to get my Ph.D in political science. So, I entered the program in political economy at Princeton in 2002, started this job in the fall of 2006, and got my Ph.D in 2007. I do a mixture of work; my primary interest is in bureaucracies, in particular, government bureaucracies that administer government programs, but I have some interest in law and courts as well.

jur: When did you first participate in academic research, and did you do any during your undergraduate years?

Jordan: I did. As an undergrad, I majored in psychology and minored in education, and I worked very closely with a professor in the education department. He was doing research on moral development, basically, the way that people change over time in their lives in the way that they think about moral problems, and he had done hundreds of interviews with college undergraduates in particular. He was working with a theoretical framework which classified and named stages of moral development and named stages of moral development, and the goal of the project I was working on with him on was to code the transcripts of these interviews according to the appearance of traits that are considered to be characteristic of one stage of moral development or another. So, I did all of this coding for him during my junior or senior year; it was probably a 20 hour a week job or something like that.

jur: You mentioned that you worked as a social worker and that you did work in psychology. Does that in any way inform the work that you do now?

Jordan: Yes and no. I think my majoring in psychology was driven by a desire to help people. I wanted to find a way in my life to help people around me; that was the bottom line, and

that's why I went into this job in social work. Ultimately, I went back to school because in my own personal experience on the job, I began to doubt my ability to help people in that way, to be the most effective I could be as a direct service provider. I went back to school with the intent of getting into management or research and to try to understand what would make programs better, what would make them more effective, what would make them more helpful to their clients. One of the frustrations I experienced when I was working was the lack of self-evaluation by programs that tried to help folks. There was very little questioning among people who worked on the front line. Maybe more importantly, people who worked in upper management and in the funding agencies never asked, "is what we're doing actually helping the people that we're trying to help?" I mean, in some cases it seemed to me that it was possible that some of these things would make people worse off. There's very little questioning about that and that troubled me; I went back to graduate school hoping to develop the ability to be more critical of these programs and to do research that would actually ask these questions. But I also went being troubled by this lack of critical-ness in these organizations, this lack of being concerned about even checking whether or not things were doing good and wondering why that was. Why is it that this doesn't happen? Well my instinct was politics, but beyond saying something vague like that I couldn't say much. What is it about the political process, the process of allocating funding across organizations, the process of deciding the design or the policies that these programs are going to implement? What is it about that process that inhibits these kinds of hard questions about whether we're really doing good or not from being asked? That's what led me to this work now. Understanding how information is shared, transferred, and generated in the implementation of government programs has been a major theme in my research. I'd say that another thing that's important in the work that I did and in forming what I do now is that it helps me to keep in mind that at least for me, when I think about government and what it does, when I think about politics, what really matters to me is how it affects people on the ground. So, I tend to be pretty uninterested in things like "who wins the presidential election;" it's much

more important for me to understand what government looks like from the point of view of the person who's applying for, say, disability benefits or worker's compensation, or the person who is being arrested by the police, or the person who is trying to sue their landlord over a failure to provide something under a rental contract. I would think of it like the tip of the spear of government is what matters to me. I try to keep that front and center in my mind when I do research.

jur: It seems like a lot of your work is driven from your interest in helping people. What do you think of the ability of political science research to actually have such an influence?

Jordan: (laughs) In some ways I came in with that question: why doesn't research get done, why doesn't research that would tell us whether these programs work get done, and, when it is done, why don't people pay attention to it? I came with those questions, and what drove me into graduate school in the first place was I wanted answers to those questions. I have better ideas now about why that is true, but it's more clear to me now than ever that it is true. In other words, that research doesn't get done that would actually answer these hard questions. When it is done, most of the time, it is ignored or it's misused. That's a political fact about the world, and I am powerless to change it, not just because I am a political scientist, but because by definition a political system is a system in which people with different interests are competing for scarce resources, and part of what people do when they're competing for scarce resources is they're very careful to control information and to control their image, and that's just a fact about human existence, there's nothing that's going to change that. And so the ability of political science, or the ability of any research field to have much of an impact on the design of government programs or on the design of non-profit programs is very limited; it's limited by the reality of the social system that is defined by any political world. What I feel like I can provide is the same kind of answers that I was looking for to other people—why does it happen? I can't change that it does happen. The thing that I can do as a political science professor and that I think is immensely important is to connect with my students, with my undergraduates in particular, and be a person to them that is more than just a person who provides a lecture and a test and a grade, be a person to them that helps them to figure out what they want to get from their experience in college, define that for themselves, and get it. That's actually not an easy thing to do, and as a professor you are in this position where you're evaluating your students, so it makes your students naturally a little wary of you. And so the way I try to live out what I was hoping to get when I was going through college by being a person who is very inviting to undergrads, to have them feel that they can they can be open to me about their thoughts, the classes they're in—; even my own class, what it's doing for them and what it's not doing for them and to encourage them to come and try to think through what they want to get when they're here and how they can get it.

jur: You talked about your classes—you're sort of known for experimenting with unconventional teaching methods. Could you talk about those and maybe talk about how they relate to your research and how they inform each other?

Jordan: I wish I could say that I have a systematic theory or a well thought out reason for the way that I teach and all the experimentation that goes on in my classroom, because that's true, I like to do stuff unconventionally sometimes just because it's unconventional (*laughs*) without a whole lot of reasoning. I mean, I've been more systematic in some classes than others about my experiments, but I will always experiment (*laughs*), sometimes for better and sometimes for worse. How does my research inform that? I don't think that has a lot to do with my research at all, actually; it has more to do with the relationship I want to establish with my students. I just don't know any other way to relate to my students other than a way that feels honest to me, and the truth is that I don't know anything that my students couldn't learn in a semester. There's nothing that I know, when I'm teaching a class, in terms of the class material that any student couldn't learn on their own, without me. In many cases, students know more than I do, and they may know everything that I have to teach them already, but just not know the terminology for it, just not have the language or know how to recognize that they know it. So I'd say one thing that's important to me in the classroom is to not let that knowledge that students have go untapped, to not let it sit there, to not go through the charade of pretending like I know everything and the other sixty people in the room know nothing; that's just absurd, right? Part of what I'm trying to do in the classroom by doing things that are unconventional is in some ways to wake people up; let's do something where there's actually participation going on. When I teach the class on the presidency I run a simulation of lawmaking, and part of what I'm trying to do there is just to have students contribute to the actual knowledge, the actual information, the actual learning that's happening in the classroom. The great thing about the simulation is that students themselves are coming up with the strategies that they're going to play to try to manipulate this legislative system, and it's their own creativity and their own ingeniousness, really, that we end up learning about and we end up learning from. In my view, this is just common sense, that learning from sixty people is way better than learning from one person, and the first task in the classroom is to get people comfortable with actually speaking, so that people can actually learn from them. Everybody in that classroom has something that somebody else doesn't know, but people are very inhibited; students are very inhibited, scared, to speak in front of people, so by doing some experimentation, in some ways I'm also trying to make it okay for people not to make mistakes, because I'm up there blundering every day. I'm trying to create an atmosphere where spontaneity is happening and we're having fun and nothing has to go perfect, and, in some sense, we want things not to go perfect, we want things to happen organically in the classroom. I'm trying to draw people out, maybe that's a short way to say it.

jur: To change tracks a bit, over the past few decades, political science has changed considerably, and you are're a part of that change in your research, particularly in, for example, using mathematics and economic methods in research. Could you embellish on how these methods have changed the field and how you use them personally?

Jordan: Well, you're right that the field has changed. I guess

it's important to say that these methods started to be used by people who called themselves political scientists as early as World War II, as early as the 1940s, and in some sense, economists have been asking many of the questions that political scientists ask using formal logic or statistics for much longer than that; they've been doing it since the mid-19th century. When I think about political science changing, or when I think about the change in political science that relates to these mathematical methods, it's not so much that I think political science has been done differently, it's that the reception of these methods in the mainstream political science journals has changed, so that when people now think of, say, theoretical papers that try to develop or illustrate their ideas using mathematical models, they think of that as just an instance of political science. They don't automatically assume, "this is not our field." This has opened up a space in this career for people like me, who are most comfortable working with mathematical models, who want logical rigor in what they do. The fact is that you can become a political scientist who specializes in mathematical models now, and there's lots of jobs for people like that, and there's plenty of training for it; it's not exotic anymore. It was exotic in the 1970s, it was even still a little bit exotic when I first started graduate school; it's not anymore, now it's just as straightforward and normal to try to develop as a researcher who uses those kinds of tools as it is to become a researcher who specializes in public opinion polling, which we think of as the core of political science. Well, what's really happened in the discipline is that there's a lot more diversity in the field now, I guess that's how I'd put it. Did you ask how that informs my research?

jur: Yes, does that give greater depth to your research?

Jordan: I don't know that it gives greater depth to my research; I've really struggled since I've been here in how to use these tools that I have. In graduate school I concentrated on building my skills in these tools—I concentrated on becoming a competent applied mathematician, essentially. As a result, I did very little in the way of reading actual political science or reading what people were writing in political science at the time or had written before, so I came to a classic in American politics like *Why Parties?* by John Aldrich, which, if you've taken PSC 202 under Gerald Gamm, you've read that book, but I hadn't read it until two years ago, because I was busy learning math. Just another example, the classics in political philosophy—*Leviathan* by Thomas Hobbes, hadn't read it until two years ago, because I was busy learning math. The *Federalist Papers*—I had read maybe one or two when I was in graduate school, but other than that, hadn't read them until a few years ago. And so since I've been here, it's like I got out of graduate school and the time of my training was over; now, I had to actually write, and since then, it's been a struggle for me to try to take these tools and integrate them with real questions and to use them in a way that builds on the existing massive amounts of knowledge and wonderful work that's been done out there in political science that I never had time to read. It's funny, for me, what deepens my research is actually the non-mathematical stuff, because that's where I'm growing (*laughs*). I'm where I need to be and more on math, and now I have to learn about the

substance and learn about what the interesting questions are and what the background of those questions is, and what the more soft or intuitive theoretical ideas are and how to use these tools to contribute to those intuitions. This makes me glad I'm not an economist, actually, because like I said, from my perspective, what the growth of mathematical modeling has been is really just a diversification of the field; it's made the range of methods you can use in the field broader; well, thankfully, our field also includes people who are historians; thankfully, it includes people who are sociologists, in effect, in their methodology; thankfully, it includes people who are anthropologists in their methodology and focus on describing in intense detail the lives of a very small number of actors, because that's the kind of work I've been relying on to turn my modeling into something that actually speaks to people who know something other than math (*laughs*).

jur: Could you outline some of your recent work?

Jordan: Sure. I just sent a paper off to a journal hoping that it will be published, and that paper is trying to understand how interest groups influence the rules and the procedures that govern the operation of or the implementation of government programs. To give an example of what I'm talking about, when the bill called the Dodd-Frank Act passed a couple of years ago that overhauled the system of regulation of financial markets, that bill was criticized because much of what the bill did, rather than actually setting substantive restrictions on what financial firms and financial traders could and could not do, instead of actually setting restrictions directly, it authorized federal agencies to make regulations that would in fact contain the substantive restrictions on behavior. One thing that's interesting about that to me is that from the point of view of the interest groups involved, this means that they don't just fight over the legislation itself in congress; it's not just legislators they're lobbying directly over the Dodd-Frank Bill, but also, once that bill passes, they're going to go do it all over again in the bureaucracy; they're going to have yet another big battle over those regulations coming out of the executive branch, and that battle actually is not just going to be fought in the federal agencies, but because our court system is so involved in the process of regulation, they're also going to be litigating over the actual content of the policy. And so it's been the case that most political scientists, when they thought about how legislation ends up structuring the process of implementing policy, have thought about it from the point of view of the legislators, where the idea is, well, legislators have an idea about what they want to happen in the implementation process, and they must be structuring that process in a way, they must be putting down rules and legislation on how policy would be made in the executive in a way that's good for them. As I've thought about stories like the one about the Dodd-Frank Act, where we know that these interest groups are going to be not just battling once in congress, but they're going to have to it all over again in the bureaucracy and all over again in the courts; and, in fact, long after these congressmen are gone, they're still going to be doing it, when I think about that, it seems to me that congressmen, legislators, people who hold office, they don't seem to be the most appealing central actors in an explanation or a description of the process through which the rules that structure policy implementation get defined. It seems to me that the players who have real stakes in the structure

Jordan

of federal programs are the interest groups who know that they have these long-run interests. When we think about the process through which those structures get actually adopted in congress, we should be using a theory that puts interest groups at the center and thinks about congressmen instead as people who happen to be able to cast the votes, but really are just being pushed around through either campaign contributions, through the provision of information, or through just outright persuasion by the efforts of interest groups who have long-run interests in the program. In this paper, what I do is I use a formal model that basically demonstrates the logic of a theory of the structure of government bureaucracies in which interest groups are the primary actors driving legislative constraints on bureaucratic structure. What the paper ends up doing is suggesting that there should be a connection between the kind of biases toward different groups that are written into legislation and the actual volume of lobbying activity that goes on to influence the federal bureaucracy or the volume of litigation that goes on in the courts. That was a surprise, that's not something I expected to get out of the model, that's one reason that we do mathematical modeling is sometimes we don't realize what the implications are of our assumptions, and this happens to be an implication. It's actually good news in some sense, because the volume of lobbying and the volume of litigation is something we can actually potentially observe. So if I'm right about this alternative perspective on the way that government programs get structured, then it's possible in principle to go out there and look at some data that might show that that's the case.

jur: In recent months, political science has weathered considerable criticism, particularly for unreliability of predictions; the U.S. House of Representatives even passed a bill to eliminate National Science Foundation grants for political scientists. What do you think of these criticisms, and what can political scientists and other researchers in the social sciences and humanities do to legitimize their fields in the public eye?

Jordan: I'm not sure that I'm too concerned about legitimizing our fields, frankly. You know, some of this debate gets framed as a debate about whether political science is a real "science." And sometimes when people ask that question, is it a "science," they seem to mean, can it tell us things about the world that we don't already know? And can those things actually be demonstrated to be true, in some sense, by showing that it can predict things reliably? Both of things are probably, for the most part, not true. It's probably the case that we can't say something people don't already know, in some sense you know that's my attitude from my attitude about the classroom, which is that there's probably nothing that I know that my students don't know already. And it's also just our track record; for whatever reason, it's incredibly hard for us to show that whatever we predict or whatever way we want to characterize political processes can be demonstrated unambiguously to be the hard and fast truth with a whole lot of data; we don't go about proving the existence of the Higgs Boson or something. We just can't do that. So if that's what congress wants out of a program they fund through the NSF, then they shouldn't be funding political science, period. The contribution we do make is basically to people like me, frankly. And I don't mean people like me who have a cushy job at a nice

university. What I mean is people like I was, I guess I should say, back when I came back to graduate school. I came back with real questions about the world; I was troubled. I was sad about how indifferent the people I interacted with in my work were and how closed off they were to questions about whether or not we were doing our clients any good or whether we were even potentially doing them harm; I was troubled by that, I was sad about it, and because I was sad about it I wanted an explanation, I wanted to make sense of it. That's what a lot of people are coming to school for, obviously you come to get a job, but if you were just coming to get a job, we wouldn't have a liberal arts education. You come to these classes and you come with questions, and these questions have to do with "why do things happen?" "why is the world the way it is?" That's essentially what I think of myself as doing in my research—engaging in that asking questions about why things happen the way they do and offering answers. Most of the time, the idea of a right answer in the first place is sort of vague, whether there is such a thing in any given case; often times all I'm trying to do is articulate my question in a clear way, without even trying to get it answered. That is a process that is personally satisfying to me and does offer me some peace (*laughs*) about the ugly, ugly, realities of politics. Ugly. Morally ugly, I think. It brings me some peace to have these explanations, and I think that as a political scientist, what I can do is help others go through the same process for themselves, to build some understanding, to build some sense of why things happen, beyond just "there are bad people in the world." That's a very specialized thing, not everybody feels the need to have those questions asked and answered. Not everyone feels the need to have things laid out in a logical way, not everybody feels uneasy until they have that, but as a teacher, I'd say there's about 25% of my students for whom trying to give explanations, to give coherent explanations of why things happen the way they do makes that person say, "wow, I'm really glad I came to class today," "I really like thinking about this." And, that's the product I'm selling, basically, and not everybody likes it, not everybody wants that product, and that's perfectly fine. It'd be the same thing if I made cars or roller skates; I have a product that appeals to some people and that's what I'm providing and what I think we provide as a field. Given that, actually, it's a private good, by the way, so there's not a particularly good justification for the government funding it, in my mind. Let me put it this way, would I rather have my clients from several years ago have more funding for housing, or would I rather there be an NSF program for political science? Hands down, I'd rather have more funding for housing.

jur: What are some of the more significant roadblocks, personal or professional, that you've encountered in your career?

Jordan: Well, I'd say first of all that accomplishing what I need to accomplish in research, what my obligation to this institution is in terms of research, has been hard for me; I have just really struggled with it. I think of myself as being behind the curve; I haven't accomplished as much as I should; I'm worried about my ability to meet the standard, and that's been with me almost right from the beginning of the job. What has made that hard for me has been a question that's always been in my mind, and the answers to that question have varied over time. The way I

see it right now, what I struggle with is getting research out the door. I think the roadblock for me is a tendency on my part to try to do research that will be unassailable, that will actually meet the standard of "science" like I was talking about before, the idea that what I'm going to produce is going to be an answer to some question that actually answers the question. Holding my own work to that standard has caused me to have a huge amount of papers that have been written but never sent out the door, because I don't think they're good enough. It's also caused me to take a long time writing papers, because I don't want to write a paper when I'm pursuing that standard until I can see a clear path to a paper that answers a question definitively in a way that will convince everyone else in the world. Whether such a paper is attainable or not—I feel like I've learned that if it's going to be attained, it's not going to be attained by aiming for the target itself; the right way to overcome this hurdle is to try to keep in mind that all I'm doing is writing an article, and a perfectly important thing, and a thing that journals want out of articles and other academics want out of articles includes just raising questions without answering them. It includes offering tentative explanations, offering hypotheses, offering perspectives, and obviously a lot of people would think that an article that does that is less good than an article that does something more, and actually I agree with that, but those articles, the articles that just raise questions, the articles that propose hypotheses, the articles that propose alternative ways to think about those, when I think about it as a student—those articles have meant a lot for me and those articles I'm perfectly capable of writing. I don't have too hard a time doing it, and I enjoy doing it, when I'm not too worried about how they'll be received (*laughs*). But for me, the hardest hurdle is that putting yourself out there, putting a piece of your work out there to let it be criticized and knowing that it will be criticized, because our work is criticized brutally; you send it to a journal, and you get reviews back and they can be pretty rough, and so being ready to deal with that and being ready to put myself out there over and over again—that for me is the hardest thing, the hardest roadblock.

jur: How would you suggest undergraduates get involved with research, particularly in your field?

Jordan: Ideally, the first answer would be, sign up as a research assistant for anybody. So, first of all, don't be selective; if someone has research work, do it. If you're an IR major and someone's working on congress, just do it. If you love American politics and you want to go work in Congress as soon as you get out of college, but the only person who's hiring is someone who does studies of civil war in sub Saharan Africa, just do it. If they need it done, do it. That's the first thing, because there's something to be said for just seeing what research is like, and actually, the topics vary, but the basic process of research doesn't really vary across the topics, and I think if you're interested in pursuing a career in research, you want to go ahead and find out what it's like, find out what the day-to-day looks like. So I'd say don't be selective about who you work for as a research assistant. Now, all that said, that's the ideal advice—the problem is that right now, I feel like we don't have enough work for undergraduates who want to participate in our department at least; I don't know about other departments.

And so I guess the right question for me to answer is: if you're an undergraduate interested in political science research at the University of Rochester, where we are lacking in RA jobs, what's the best thing to do? You don't have to work in the political science department if you want to go to graduate school in political science. In fact, it's immensely valuable, no matter what department you go to, to have an experience working with research; do it in the psychology department, do it in the anthropology department; probably a good idea to stick to the social sciences if you're going to, but you can also try philosophy or history. For me, my personal relationship with the guy who I did research for—he was a huge support for me in college, I'll always be grateful to him, in some ways I think of him as a third parent for me. And that happened because he invested in me as a person who worked hand-in-hand with him on something that was important to him. I encourage you to go find anyone, anywhere, with whom you can develop a working relationship with. Obviously, the kind of close relationship I ended up having is not going to happen for everybody, but still, and it's not only in political science but across the social sciences—the topics, the questions, vary, but the process of research is very similar. So don't be selective in the sense that you have to come work for the political science department. The other thing I would say, though, outside of actually going and working as an RA, is to seek out "W" classes. I think the thing about research, at least, it's the thing about research that's hard for me, and having advised thesis students and watched a lot of students go through the process of trying to develop a thesis but not being able to get it all the way to a thesis level, I think one of the hardest things is to learn how to write from your own position as your own person. You're left to actually write something down and say, "I think this is true. Here's why." And it has to be what you think is true, that's hard, and I think the more practice you can get in being out front in that sense, and being the person writing the paper, making an argument, making your own argument; the more experience with that you can get, the more you'll know about that process for yourself and what it's like and whether you like doing it, and it's just an incredibly important skill to gain if you think you might be interested in going into research. A lot of what we do as researchers, long before there's any data, long before there's any experiment, long before there's equations on the whiteboard—there's a person sitting down at their desk saying, "here's a question that I have," "this is my question," "I want to know X," and "I think that the right way to answer it is this way," "I think it's this data," or "I think it's this experiment," or "I think it's this mathematical modeling approach." That is a necessary step in any research process; somebody has to own it, and it has to be the researcher. And actually, that's something you can do in writing a term paper, too, is say, "what do I think is the right way to answer this question?" and then own it and do it. That's the core of every piece of research out there in every field, and it's an incredibly difficult position to be in, and it takes practice to get comfortable with it. Go ahead and start (*laughs*).

jur: Finally, do you have any general words of wisdom for our undergraduates?

Jordan: The best I can come up with is I see a lot of undergraduates either not have an idea of what they're going to

do when they get out of school and worry about that a lot or I see undergrads who have an idea of what they're going to do when they get out of school, and then they are very selective in what they do as an undergrad in trying to prepare for that one thing they want to do. This probably sounds demeaning but recognize that you still have a lot of learning to do, and I don't mean that in terms of, "I know a bunch of stuff and you don't," or that you're young and stupid, or young and inexperienced, what I mean is that you'll be learning your whole life, about yourself, about what you like, about how to do whatever it is you're doing; how to wash the dishes, how to relate to your friends, how to relate to academic work, how to read a magazine; these are things that are going to change over your life, and you're going to be learning them right up till the day you die, which could be decades and decades from now. You don't have to learn everything in the next four years. You don't even have to learn everything in the next twenty years. You can just enjoy learning what you're learning now, and be assured it won't stop (*laughs*). Be assured that the opportunity cost of taking a class in anthropology as opposed to taking a class in economics isn't as great as it may seem, even if you want to go be a banker, even if you want to go to graduate school in economics. So, that's my one piece of advice.

CHEERS: A SOCIOLINGUISTIC COMPARISON OF AMERICAN AND BRITISH BEER ADVERTISEMENTS

Lucas Piazza, 2012

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Beer is enjoyed by millions of individuals in numerous cultures. Yet, each culture perceives the intoxicating beverage slightly differently. Many highlight the vast similarities between British and American culture, yet there are truly plentiful differences. An obvious disparity is the consumption of beer and the cultural norms surrounding this drink. Advertisements are largely representative of these cultural perceptions, and careful analysis reveals the true perspective American and British cultures have towards beer. The employment of humor, the selection of vocabulary, the choice of imagery, and product placement are all important aspects when considering the true message of an advertisement, and the United States and the United Kingdom hold different beliefs on the appropriate approach to using each component. Through a variety of methods, this study explores the sociolinguistic differences between beer advertisements from each respective country and draws broader cultural conclusions based on these analyses.

INTRODUCTION

Located just over three thousand miles away from New York City, England does not seem too foreign of a land and is often referred to colloquially as just "across the pond."¹ As one considers America's strong historical connection with Great Britain and the simple truth that both the United Kingdom and the United States have the same *de facto* language, the separation between the two countries has a tendency to shrink even further.^{2,3} It is easy for Americans to feel a connection to the country that bore our founders, for we feel connected through history, tradition, and language. I certainly gravitated towards this naïve perspective in preparing to study in London for a semester. As I boarded a plane at Newark Liberty International Airport destined for the United Kingdom, I was confident in my ability to communicate as soon as I disembarked from the cabin. However my perceptions were not upheld by reality, and the first cultural aspect I latched onto was the vast linguistic differences I felt engulf my senses. So great was this feeling that I began to keep a journal detailing the differences so I could

help myself learn this unexpectedly foreign dialect. My four-month immersion into British culture surprised me in many ways and revealed not only a great separation between American and British rhetoric, but between American and British culture as well. It became evident that the historical and informal connections America may have with the United Kingdom were not strong enough to consider the two in parallel, and I left feeling as if the physical divide between the countries was closer to thirty thousand miles.

Around the same time that I began to adopt the dialect of Londoners, after approximately one month of residence, and found myself more comfortable with British English, I noticed one of the greatest cultural differences between my native United States and my explored England – the consumption of alcohol. I am fascinated by the consumption of all things, be it tangible, edible, or abstract, and thus my mind naturally fixated on the tremendous disparity between beer consumption in western countries. At the close of every working week, my coworkers in the marketing office in which I interned would file out at 5 o'clock and head to the pub next door. If the Crown and Sceptre Pub was too full, we simply walked to the next corner where undoubtedly another pub with dark wooden booths and crimson carpet would graciously welcome our thirsty lips. Once inside, our discussions would drift from work-related issues to sporting events and upcoming attractions happening in the city. Never was there intent to become intoxicated and unruly, but rather to unwind after the working week and be in good company. This first-hand experience not only stood out as completely foreign, but it was one that I had rarely seen recreated in America. I have worked in the corporate world for two consecutive summers and the communal bond of beer was rarely shared amongst co-workers. Occasionally, an ice bucket full of domestic beer would be placed in the communal kitchen on a Friday afternoon, but it was expected to be consumed in the office and then employees would retire once more to their desks. The stark contrast between British and American cultures was one I could not shake, and it led me to analyze the role beer plays in each country, and specifically how it is advertised.

Amongst advertisers it has long been debated if advertising affects culture, or whether the opposite: if culture affects advertising. This research project seeks to explore that very question by comparing beer advertisements in both the United States and the United Kingdom, paying particular attention to the language used in each, and extrapolating these data to further understand how each respective culture views beer consumption.

Besides the delicious nature of the drink itself and its intoxicating effects, this study has implications that are important for understanding the global impact of advertising, an industry that is rapidly changing. The latter decades of the twentieth century saw a trend towards globalization in the advertising industry. Smaller independent agencies merged under the leadership of large holding companies, and the business saw clients crossing the Atlantic with global expansion in mind.⁴ The result of this movement was that by 1990, four of the top U.S. agencies were owned by British companies, and five of the ten top agencies in Britain had American parents.⁵ Currently, WPP is the world's largest communications services company by revenue. It has its headquarters in London, UK, and companies located in 107 countries.⁶ It is impossible to deny the effects this has had on the advertisements themselves, and new and different cultural aspects have been introduced into the campaigns created. Products and their associated marketing strategies can now be standardized, allowing a more consistent message and a more cost effective solution. However, advertising agencies cannot fail to realize the differences amongst cultures, even in countries as similar as England and the United States. This study seeks to illuminate precisely these differences.

METHODOLOGY

Throughout the execution of this sociolinguistic project, I employed multiple research tactics. It is impossible to ignore my own personal experience in which I directly interacted with the British people and saw first hand how beer was perceived and consumed by locals in London. This experience served as my first fragment of research. To supplement my own observations, I sought out individuals at the University of Rochester who had lived in England at some point during their lives. Additionally, I had extensive conversations with my supervisors at *umi Marketing*, both of whom live and work in London. All of these individuals' specific demographic information can be found in Figure 1, located in the Appendix.

To further this first-person research, I conducted my own visual and linguistic analysis of a variety of beer advertisements, from print and out-of-home ads, to commercial and digital ads. A collection of videos and print pieces is also located in the Appendix and should be viewed in tandem with this article. It is understood that first-person research can only bear so much weight, and thus this undertaking relied heavily on secondary research and academic articles. Much has been written on the differences between England and the United States, and many of these insights are woven into my research and have influenced my perspective throughout the project.

Although I attempt to cover many aspects through the breadth of my research, I recognize that there are inherent limitations and shortcomings. The first is that my experience with the British people is largely the reflection of city-dwelling

Londoners. City culture does not necessarily reflect the ideology of an entire country. Furthermore, media and advertisements tend to be more prominent in urban centers simply due to the high concentration of consumers. Had I explored more rural areas of the country, my impression of British culture may be different. Furthermore, my own analysis of American culture comes from my own assumptions. Having resided in the United States for the entirety of my life, I felt my own perspectives were sufficient in providing the contextual framework upon which I studied American advertisements and the culture's perspective towards beer. It is possible that had I included first-person interviews with other American citizens, my findings would have differed and the richness of the study would have been enhanced.

FINDINGS FROM SECONDARY RESEARCH

Linguistics and culture are dimensions of a society that are easily united and understood concurrently. Differences between American and British culture and rhetoric allow for the two countries to be placed into distinct categories regarding marketing strategies. In advertising terms, the United Kingdom is very much a "soft sell" market, emphasizing subtle audience-oriented messages, whereas the United States employs a "hard sell" market, capitalizing on facts and placing products in the foreground.^{7,8} This soft sell/hard sell dichotomy provides an interesting contextual framework that influenced my perspective in later research and shaped my own analysis of the beer advertisements.

There are numerous reasons for Britain's soft sell economy, and many correlate with deep-rooted historical traditions. Citizens of the United Kingdom have long viewed mass media, especially television, with pessimism and cynicism. After the recent NOTW hacking scandal that undermined Rupert Murdoch's media empire, a survey showed that 44% of British citizens have lost further trust in large media companies due to the hacking incidents.⁹ This disconnect between mass media and the public largely results in consumers ignoring commercials and adverts entirely. Culturally conscious advertising agencies have learned to combat these norms and understand that in order to disseminate their clients' messages successfully, they must employ subtleties and intrigue. British adverts are commonly composed of puns and dry satire, an attempt to prove to citizens that the products being advertised are sound for the intellectually acute consumer. Rarely in British advertisements will the product itself be featured in the forefront. Rather, stories surrounding the product are constructed to build anticipation and curiosity, subtly revealing the product at the close of the commercial.¹⁰

The American advertising landscape could not be more different. On average, United States consumers are bombarded with over 247 commercial messages daily.¹¹ The overload of information on consumers results in advertisers fighting to have their message heard, creating a hard sell market. Product messages must be clear and concise, and the product is often pushed to the forefront of the commercial from the opening scene and remains there until the spot concludes. Humor is certainly employed, as in British advertising, yet it is entirely different. In America, humor is often straightforward and vulgar, serving as a final attempt to hold a customer's attention.¹²

FINDINGS FROM PRIMARY RESEARCH

First-Person Interviews

First person, qualitative interviews are a tactic that many market research firms employ in the data collection process that aids the creation of an advertising campaign. I found it slightly ironic that in reverse engineering the meaning of beer advertisements, I resorted back to the same methodologies to gain cultural insight. The interviews conducted focused primarily on the cultural significance of this study and largely ignored the linguistic aspect.

Similar answers and trends emerged through each interview, which centered around one word – respect. The first of these trends was the disparity between American and British youths' consumption of beer. The second evident trend was the history of beer in the United Kingdom. Collectively, these two aspects made it blatantly clear that the ways in which British culture perceives beer are vastly different than the ways its counterpart just "across the pond" does.

In the United Kingdom, one is able to purchase alcohol at the age of eighteen, may consume it with a meal at age sixteen if accompanied by an adult, and can be served at home by parents regardless of age.¹³ In comparison with the United States, where the legal drinking age is 21 regardless of environment, respondents felt that British youth start drinking earlier than their American equivalents. However, all conversations yielded a similar truth, that while British teens may drink younger and consume more, they are much more in control and have a respectful relationship with beer. Two individuals explained that since British citizens can legally drink younger, their parents were heavily involved with the alcohol experimentation process. They spoke of a trusting relationship between parent and child that allowed for a safe drinking environment, and did not perceive a similar relationship to exist in America. This legacy of respect surrounding beer is one that speaks volumes about Britain's larger cultural view toward the drink.

Throughout the United Kingdom's extensive history, beer has played an important role in the culture. One obvious consequence of beer's importance is the sheer number of pubs located in these countries. The prominence of these establishments and the prevalence of beer in British society were largely important to the respondents' answers. Steve Lowy, founder and president of uni Marketing explained, "at the end of work on the weekend [pub culture] is huge." Even during the working week, one interviewee revealed that her father's coworkers would have "three or four" pints of beer during the lunch break and return to the office for an afternoon full of productivity. Both sexes enjoy going to the pub, and more often than not, beer is the drink of choice amongst pub-goers. The purpose of pub gatherings is not for intoxication, although that can often be a consequence, but rather for socialization and kinship. In this sense, respondents regarded beer as a drink emphasizing community and loving feelings.

It would be inaccurate to make a blanket statement regarding Americans' consumption of beer, because behaviors vary amongst individuals. However, through the interviews, it was revealed that numerous United Kingdom residents have a perspective of Americans as abusers of alcohol who drink solely to get drunk. One individual responded that since she started

attending university in America, she realized that the majority of her American peers view beer as a party enhancer, whereas her acquaintances of similar age and profession in London have a much deeper respect for their bodies and for the intoxicating drink. The idea that Americans perceive beer as "sexy" and "fun" came up multiple times in my conversations, further reiterating this foreign sentiment.

First-Person Visual Analysis

The final research component employed in the process of this study was visual analysis of ads. I researched top selling beer brands in the United States and in the United Kingdom and viewed a collection of ads for these products, from commercials and print to out-of-home ads. Included in my analytical perspective were the sentiments and thoughts gained from my prior research and interviews, but I strived to view the ads without major biases. The ultimate finding was that everything I had learned before through academic articles and first-person conversations was upheld and validated.

One of the most immediate and conspicuous conclusions surrounding British beer advertisements was indeed the humor used. Take for instance the Boddington's print ad ("Made in Manchester"), which portrays a barmaid with a bulging right arm and a skinny left arm. The humor is not immediately recognized and it takes an understanding of the methods used to pour beer in the pub to comprehend the message. In the United Kingdom, beer is often poured from kegs using handpumps, rather than the carbon dioxide driven system that is employed in the United States, and thus the barmaid developed a toned right arm from years of work behind a handpump. Comparing this ad with Bud Light's "Clothing Drive" commercial reveals the disparity that exists in the employment of humor in advertisements between the United States and the United Kingdom. This particular Bud Light advertisement relies on in-your face humor that requires very little thinking or prior knowledge, thus upholding the findings of Bradley et al. (1994).

Boddington's ad also plays off the idea of beer as an important historical symbol that has a longstanding and proud tradition in the United Kingdom, a motif commonly represented in British ads. The British are proud of their pub culture and the ad resonates with that feeling, which is especially embodied in the simple copy. Both the ad for Stella Artois ("4 Ingredients") and Carling ("Barley") utilize these feelings of pride and use words that correspond with respecting beer for being a quality beverage, rather than for its ability to alter states of consciousness. A message of legacy is further communicated in British advertisements through Stella Artois' "One Day" billboard. The copy reads: "One day son, all this will be yours." The relationship between parent and child surrounding beer that was discussed in the interviews is entirely embodied in this ad and the words bring about a sense of legacy, honor, and distinction. Not one of the American ads played off the idea of history, tradition, or respect. The advertisements that came closest to capitalizing on this sentiment were from Dos Equis ("Most Interesting Man In The World") and Budweiser ("Clydesdales Donkey"). However, both of these were still overtly humorous and failed to evoke a sense of tradition as strongly as the British ads that sought to do the same.

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Rather than communicate feelings of pride and respect, many American ads employed vulgarity and sexual innuendos as a way of reaching the desired audience, fulfilling the assumption that emerged from first-person interviews. Guinness' "Legs" print ad looks classic and traditional at first, but a second glance reveals that the advertisers use a female's sexual attraction to appeal to their target demographic. The copy selected for Natural Ice's print ad ("Natt a Pult") insinuates that beer is a means to an end, and that end is a man engaging in sexual relations with a female, which is applauded in American culture. Certainly, some British ads use sexual innuendos and rhetoric in order to reach a male demographic (Foster's "Chilled" and "Bad Haircut") but the humor is more respectable and implicit in comparison to American ads. The most vulgar is Guinness' "Share One" commercial where not only is the imagery sexual, but the copy used is explicitly sex-driven. Comparison of the "Share One" commercial with Guinness' "Surfer" commercial, which aired in the United Kingdom, proves the influence of culture in advertisements and disproves the idea that advertisements are influenced by brand identity alone. Both commercials contain the same product, yet the execution of each is radically different. The American Guinness ad exploits sex, while the British ad for the same brand utilizes athleticism, power, and commitment to appeal to audiences.

The idea that the United Kingdom is a soft sell market was greatly upheld by each ad viewed. A perfect example is the commercial for John Smiths ("Diving Competition"). The spot is 38 seconds long and it is not until :37 seconds that the viewer even knows that it is a beer commercial and that the product is John Smiths. Directly compare that to Corona's "Commuters" commercial and the disparity is blatantly obvious. The spot is :30 seconds long and the scene opens with a bucket of the beer placed in the center of the frame and does not leave that location for the entirety of the commercial. Certainly not all American commercials were this obvious, but the majority made it clear that the product being advertised was beer, and many revealed the product and held it in the frame for a much longer duration than British advertisements.

DISCUSSION

The British have long been known to be skilled drinkers, and my first hand experiences in London illuminated the importance of pub culture and beer. Yet the English have a way of discussing beer and intoxication with respect and

poise. This cultural characteristic is evident in the beer advertisements targeted at British consumers. Regardless of the media, the message is one of tradition, history, wit, and charm. British consumers are less trusting of mass media and are less bombarded by marketing messages on a daily basis. Understanding this facet of British culture allows for advertisers to ingeniously insert puns and obscure humor into their campaigns, a characteristic not upheld in American beer advertising.

Quite the opposite is true of American culture. In 2010, P&G spent over \$2.2 billion on advertising alone, a figure that shows just how important the role of advertising plays in Americans' daily lives, despite a troubled economy.¹⁴ Beer is one of the most heavily advertised products in the United States, and the advertising style employed through images and language speaks volumes about how the country perceives beer. The findings of this research make logical sense and should not be surprising. Advertisers recognize the critical importance of understanding the target demographics' culture and rhetoric, and attempt to tap into this insight as much as possible in the creation of a campaign. When advertising messages closely align with a society's norms, the consumer will be motivated to perform the desired action, which is most often to purchase a product. Thus, advertisements are very much a reflection of culture, and analysis of any advert for any product should provide vast information about the culture. Beer advertisements are no exception.

The broader cultural implications this study provides are fascinating and explain some of the behaviors of citizens in both the United States and the United Kingdom.¹⁵ It is true that British youths drink more than American youths, yet beer is regarded with respect in the United Kingdom. Americans correlate beer with partying and sex, and thus similar themes are highlighted in the advertisements for these beverages. The conclusions of this study open numerous doors for further research surrounding the use and abuse of alcohol in each country and how beer advertisements may contribute to this or be representative of these realities. In an increasingly digital world, it is unlikely that advertisements will ever disappear from either American or British culture. Understanding them, their creation, and their consequences will become increasingly important as industries grow and the world truly becomes a global marketplace.

APPENDIX

Interviewee Number	Sex	Age	Location while interviewed	Years residing in UK	Place of residence in UK
1	Female	19	Rochester, NY	Age 4 - 11	London, UK
2	Female	20	Rochester, NY	Age 14 - present	London, UK
3	Female	21	Rochester, NY	Age 16 - 18	London, UK
4	Male	34	London, UK	Birth - present	London, UK
5	Male	33	London, UK	Birth - present	London, UK

Figure 1: Demographic information for first-person interviewees

THE STRUCTURAL SURVIVAL OF THE GREAT HALL OF TRAJAN'S MARKETS IN ROME: AN ENGINEERING STUDY

Jesse Cramer, 2012

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Set on the western slope of the Quirinale Hill in the center of Rome, the Great Hall is part of a large Imperial Roman complex known as Trajan's Market, built in 96-117 AD (MacDonald 1965, Lancaster 2005, Ungaro et al. 2010). The Hall is located at the north end of the complex (Figure 1) and consists of a large vaulted structure (approximately 35 m long, 9 m wide, and 11 m high at the intrados, with the

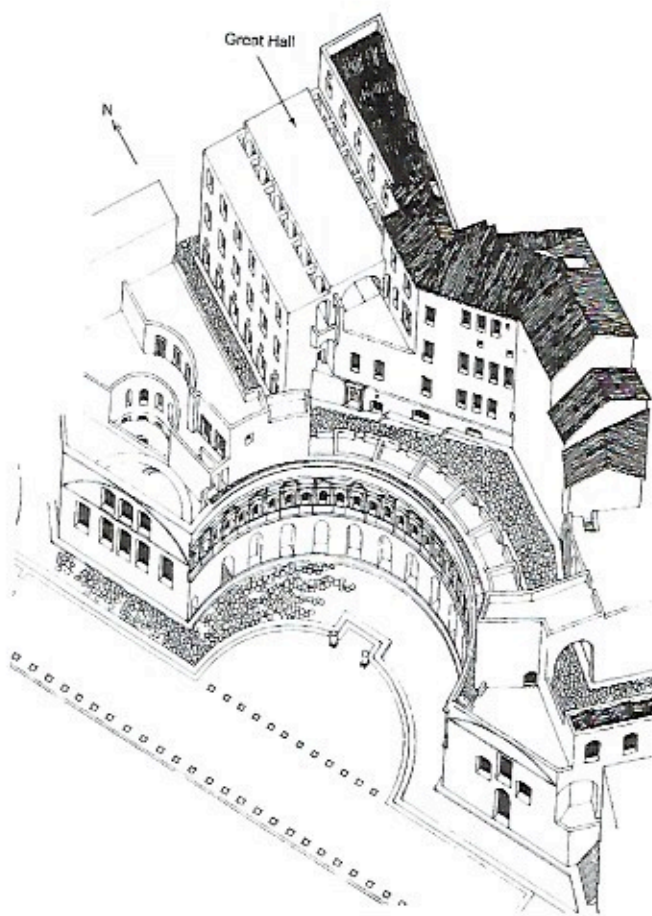


Figure 1—Isometric Great Hall

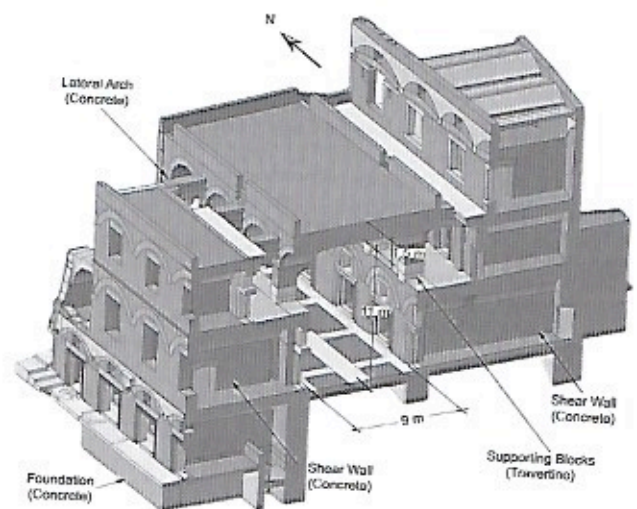


Figure 2—Great Hall Section with Dimensions

longitudinal axis oriented north-south) interposed between two multi-story buildings, which feature rows of barrel vaulted rooms (Figure 2). The entire complex is built with Roman pozzolanic concrete (*opus caementicium*), with only vertical surfaces lined with bricks. The vault itself is a monolithic structure resting on travertine blocks and transversal shear walls, connected to the adjacent buildings by lateral arches. The vault intrados forms a series of six approximately equal cross vaults while the extrados is flat. The Great Hall can be regarded as the precursor of the gigantic vaulted halls in *opus caementicium*, used in Roman imperial baths and basilicas from the second to the fourth century AD (Perucchio and Brune 2009). After nineteen centuries of continuous usage, the Great Hall and its vault are in a good state of structural integrity, having survived architectural modifications, earthquakes, and ground settlements (all typical of the history of monuments in Rome) with only localized damage, shown in Figure 3. Specifically, a fracture runs



Figure 3- Great Hall Section with Damage

down the longitudinal axis of the vault intrados, and portions of the northeast and northwest corners of the adjacent structures have collapsed. The lateral arches attached to the vault are all either fractured or completely rebuilt. Also, the smaller barrel vaults in the uppermost storey of the eastern building are missing. The entire monolithic vault of the Great Hall, however, remains standing.

Previous engineering studies of the Great Hall have been limited to analyzing simplified models, focusing primarily on the stresses in the main vault under static gravitational loading and on the function of the lateral arches (Swayngim 2008, Croci et al. 2008, Perucchio and Brune 2009, Brune and Perucchio 2012). Also, the structural effects of the major Renaissance modifications made in 1574, when an intermediate vault was added and two circular openings (oculi) were cut in the Roman vault (Figure 4), have not been investigated before. In the present study, the monument is reconstructed in all its structural details, both in its original configuration and as it was modified in the Renaissance. Structural analysis is performed via 3D finite elements (FE) modeling to evaluate the effects of static gravitational loads, natural vibrations, and seismic actions. The FE analysis identifies the deformed shapes and, from these, levels of tensile or compressive stresses throughout the structure. If nuclei of critical stresses (i.e., at or above the tensile or compressive strength of the opus caementicium) are detected, these can be correlated with existing fracture lines or missing structural elements in order to identify possible causes of damage.

2. OBJECTIVES AND METHODS

2.1 Research Objectives

Several structures built by the Romans shared characteristics with the Great Hall of Trajan's Markets. The Baths of Caracalla, the Baths of Trajan, and the Basilica of Maxentius, for example,

were all monumental vaulted structures built using Roman pozzolanic concrete, and were erected in Rome. Yet from this set of structures, only the Great Hall remains standing. The other three suffered collapse of their primary vaults, having fractured and fallen. Although the Great Hall has sustained some damage as previously discussed, its vault remains standing and usable nonetheless, being currently incorporated into the Museum of the Imperial Fora. So why is the Great Hall still standing? What has made the Great Hall different?

This research addresses the structural response of the Great Hall with two primary objectives:

- Determine the stress distributions generated by vertical (gravitational) and horizontal (seismic) accelerations in the vault, lateral arches, and upper storey in order to evaluate the structural response to static dead loads and to the overturning actions due a peak earthquake.
- Determine the dominant natural frequencies and related deformation modes for the Great Hall complex. Identify possible critical frequencies by comparing natural deformation modes to previously suggested overturning mechanisms caused by earthquakes.

2.2 Finite Element Method

In order to investigate the structural response of the Great Hall, the finite element (FE) method is used. The FE method is a predictive computational model that provides a numerical solution to the problem of finding the deformations and mechanical strains and stresses induced in a solid or a structure by applied forces and support conditions (Cook et al. 2002). In the present case, the material—opus caementicium—is assumed to be linearly elastic; that is, it will return to its original configurations when the applied forces are removed, and the

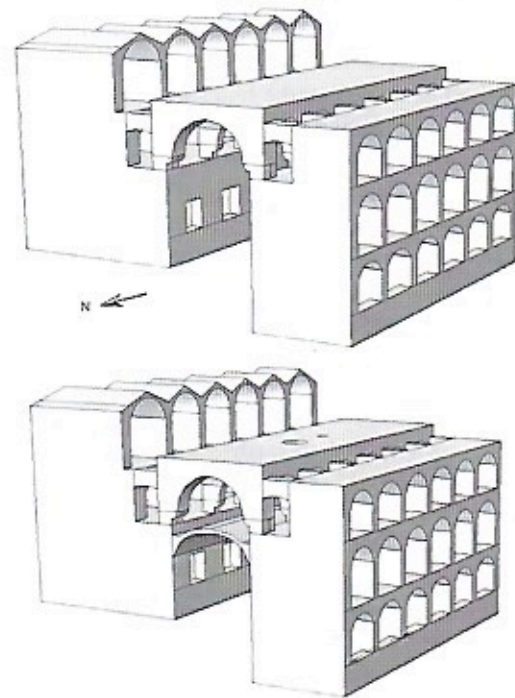


Figure 4- Two Great Halls

deformations under the applied forces are infinitesimally small compared to the dimensions of the structure. Like modern unreinforced concrete, opus caementicium can be regarded as a quasi-brittle material. After reaching a stress limit, the material will fracture (in tension) or crush (in compression). For the models used in the present study, the material is assumed to remain linear elastic throughout the analysis. Clearly, if the FE analysis reveals that calculated stresses are above the strength limits of the material, we assume that local failure by fracture or crushing has developed.

The FE model of a structure or solid consists of a finite set of connected elements, known as a mesh. An individual element's equilibrium condition is determined simultaneously by its own elastic properties and the properties of the other elements in the mesh. In this manner, the mesh can be thought of as consisting of a series of interconnected springs. Thus, the model describes how a load will be transmitted through the springs from the point(s) of load application to the point(s) of support. Behaving mechanically like a spring, each mesh element has stiffness (k), can be displaced (u), and thus has the ability to transmit forces (f) in three dimensions. The governing equations of all the elements are combined to form a system of linear algebraic equations, expressed simultaneously in matrix form as $Ku=f$, where K is the matrix of element stiffnesses, u is the vector of displacements, and f is the vector of applied forces on the elements. The stiffness of the elements is determined by the material properties of the model. For the linear elastic case, the material properties are Young's module (E) and Poisson's ratio (ν). In a static analysis, the FE model calculates the vector u under conditions of static equilibrium. From this vector, the complete elastically deformed configuration is determined together with the stress and strain fields over the entire structure.

To study the natural vibrations and natural modes of the structure, the eigenvalues of K are determined. A natural mode describes an object's fundamental response to displacement, and is comprised of a shape and a frequency. When you push a child on a swing set, the swing will cycle like a pendulum through an arc every n seconds. The shape of the system's natural mode is the arc, and the frequency is one cycle per n seconds, or $1/n$ Hz. If the child is pushed in rhythm with this frequency, he will swing higher and higher. A structure such as the Great Hall, although more complicated, acts in a similar manner. Unlike the swing, which vibrates primarily in one direction at a single frequency, a structure is a three-dimensional continuum body that can vibrate in a multiplicity of natural modes and frequencies. Thus it can be forced to displace in multiple directions—often simultaneously—and will respond depending on how it is pushed. If the forcing frequency happens to correspond with one of the structure's natural frequencies of vibration, resonance can occur. Resonant forces are very dangerous to structural integrity, as repeated application of even minor forces can lead to large stresses and strains. Analyzing the natural modes of a system is fundamental to understand how it will be affected by the oscillatory motion induced by an earthquake.

2.3 Creating an FE Model

The first step in the FE method is creating an accurate three-dimensional geometric model of the structure in question using a CAD application. Next, material properties, such as density, Young's modulus, and Poisson's ratio, are attached. The boundary conditions and loads are then applied to the structure. The boundary conditions describe how the structure is supported (e.g., the foundations of a structure are typically bounded against all movement by the surrounding soil). The applied load depicts the typical forces that the structure undergoes. Common analyses will involve a structure that is under a gravity load or a wind load. Finally, the structure is meshed, during which the continuous volume is discretized into a set of tetrahedral or hexahedral elements. From this combination of material properties, boundary conditions, loads, and elements, the previously mentioned equilibrium equations can be formulated in an approximate fashion and solved.

2.4 Architecture and Boundary Condition Variations

Several architectural and boundary condition configurations were created in order to accurately depict the Great Hall throughout its history. Although the majority of the structure's architecture remained unchanged during its 2000 years, certain distinct modifications did occur in 1574, when the structure was converted to a convent (Ungaro et al. 2010). A secondary vault was constructed, and two circular oculi were cut from the intrados of the primary vault. Thus, two distinct time frames warrant that two separate architectural models be created. The model with the modifications from 1574 is referred to as the "Renaissance" architecture, while the original structure is referred to as the "Roman" architecture. The two models are shown Figure 4.

The boundary conditions are much more difficult to properly represent than the architecture. The Great Hall is built into the Quirinale Hill, and is located at the north end of a complex of structures. Properly modeling the presence of the hill and the structures to the south is crucial in determining accurate results for both the static and dynamic cases. The boundary conditions are modeled as follows:

- 1) "Basic" Conditions: Only the vertical support under the Great Hall is considered, while the effect on vertical surfaces due to the soil or the other structures is ignored. Kinematically, the contact surfaces providing vertical support are prevented from moving in all three principal directions.
- 2) "Extended" Conditions: The vertical support is augmented by the lateral support due to the soil and the structures to the south. On the vertical surfaces, motion perpendicular to the surface is prevented.

The surfaces where boundary conditions are applied are shown in Figure 5.

In the real condition, the Quirinale Hill and the southern structures act as stiff springs, with a resistance between zero and infinity. However, testing the basic and extended scenarios is a good place to start. Due to the linearity of the analysis, the results of two tests provide the bounds of any possible results. Any scenario with stiffness between zero and infinity would yield results between those bounds. Therefore, if the basic results are close to the extended stiffness results, then no further conditions need be considered, as the third set of results would fall between

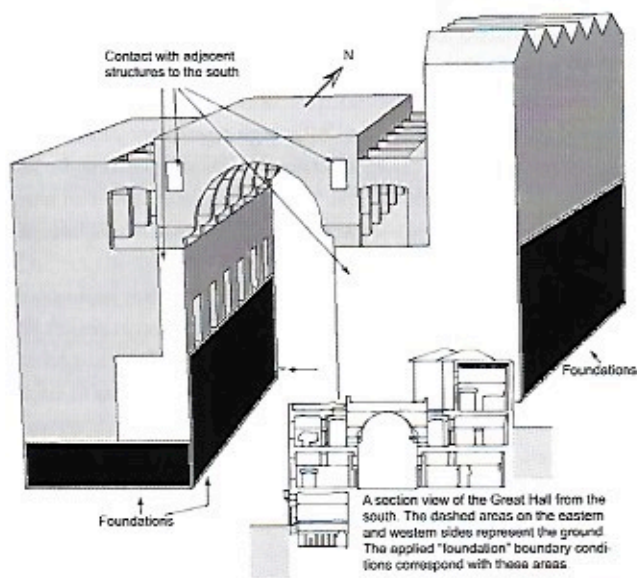


Figure 5—Boundary Conditions

the two similar results.

In the case of modeling the boundary condition provided by the southern structures, the zero stiffness and infinite stiffness results differed significantly, as further discussed in Sections 3.4 and 3.5. Therefore, representations of the southern structures are added to the model in order to provide a more realistic result support condition, as shown in Figure 6. This part of the model is not as detailed as the architecture of the Great Hall; rather, only the major floors and walls are included, since their stiffness is the dominant factor in determining the support conditions provided by the southern structures.

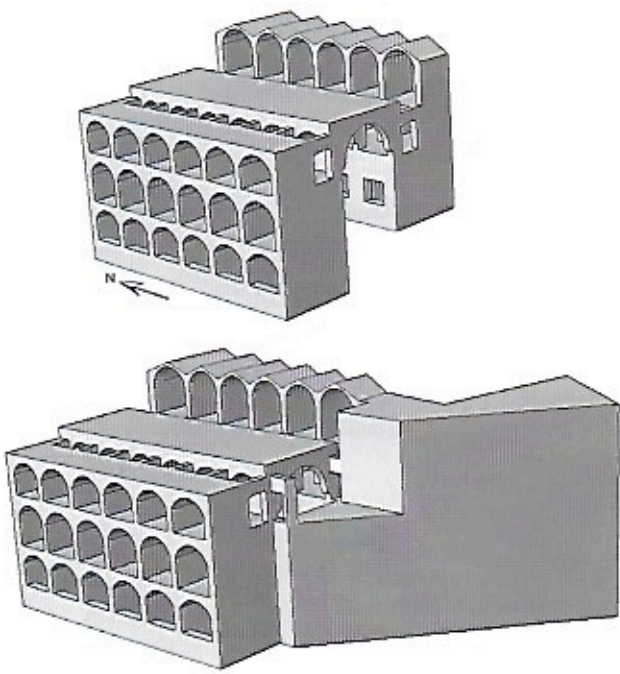


Figure 6—GH and Southern Structures

2.5 Static Gravity Analysis

We studied first the possibility that some of the damage in the Great Hall occurred when the original wooden framework was removed. The framework supported the weight of the concrete as it hardened. Eventually, the concrete was strong enough to support its own weight, and the framework was removed. However, if the concrete was not sufficiently hardened, or if the structure wasn't designed correctly, damage could have occurred at that moment. Therefore, the first FFE analysis conducted was a simple static analysis, where the only force applied is the gravitational load and the stresses corresponding to the removal of the framework can be calculated. The tensile stresses are of particular interest as the tensile strength of Roman concrete is only 0.5 MPa, while the compressive strength is 5.0 MPa. Therefore, concrete is much more likely to fail in tension than compression.

2.6 Static Overturning Analysis

If the model does not show signs of failure under static gravitational loads, then it is likely that an earthquake acceleration caused the present damage. To test this hypothesis, a static overturning analysis was conducted. A typical earthquake involves a series of accelerations of various magnitudes and directions. This analysis applies only a specified acceleration in a single direction in order to determine the stresses that such acceleration could induce. Accelerations were separately applied in the north, south, east, and west directions with magnitudes of 0.26g and 0.35g, where g is the acceleration of gravity. The 0.26g acceleration represents typical earthquake acceleration in the Lazio region of Italy that surrounds Rome (Crocchi et al. 2008). The 0.35g acceleration corresponds to a peak earthquake as defined in European modern building codes (Solomos et al. 2008). These analyses were conducted primarily to measure the tensile stresses that the accelerations could produce.

2.7 Modal Analysis

Finally, a set of modal analyses was performed in order to determine the structure's natural modes and frequencies of vibrations and the subsequent susceptibility to earthquake excitation. If the earthquake direction matches the direction of a natural mode and if the natural frequency of this mode is within the range of frequencies of the seismic action, then large displacements, or even resonance, can occur. These large displacements cause large strains and stresses, which may grow to critical levels, produce fracture, and possibly lead to structural collapse.

2.7.1 Spectral Analysis

The earthquake frequencies are determined using a separate spectral analysis. Earthquake accelerations are typically measured as a function of time. However, the spectral analysis transforms the accelerations from functions of time into functions of frequency. Thus, we can identify the relevant frequencies at which the soil is vibrating, and the magnitude of these accelerations. This signal decomposition is conducted using a Fast Fourier Transform (FFT), which utilizes the mathematical concept that every signal can be represented by an infinite series

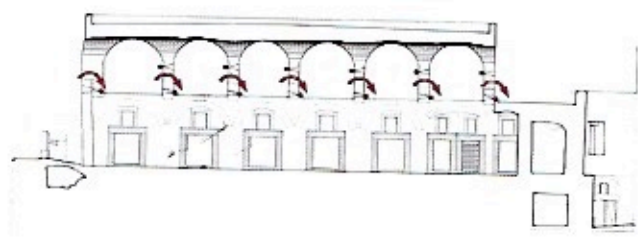


Figure 7—Crocì Overturn

of sine waves. The FIT decomposes the signal into sine waves and calculates their amplitudes and frequencies.

2.7.2 Failure Mechanism

According to Croci et al. (2008), the most dangerous mode to the structural integrity of the Great Hall is the north-south longitudinal motion, which could cause fracture in the piers supporting the main vault of the structure and bring the vault to topple over. A diagram of this type of failure is shown in Figure 7. Based on Croci et al.'s considerations, our modal analysis focused on north-south earthquake accelerations and on structural mode shapes that feature north-south longitudinal motion of the main vault.

3. RESULTS

3.1 Static Gravity

From the results of the static gravity analysis of the Great Hall, it can be concluded that gravity alone did not cause any of the damage seen in the structure. No critical tensile stresses

were measured in either the intrados or extrados of the main vault, as seen in Figure 8. The largest tensile stress measured was 0.39 MPa, falling below the critical state of 0.5 MPa. Some near critical (i.e., between 0.45 MPa and 0.50 MPa) stresses were measured in the lateral arches. Although these stresses alone would most likely not cause fracture, additional loading on these arches could lead to critical fracture. This test was re-run using all variations of architecture and boundary conditions, but the results did not change.

However, as previously discussed, concrete that had not been completely hardened would have been significantly weaker than fully cured concrete. Therefore, the critical tensile stress would have been below 0.5 MPa. We do not know the strength of the concrete in the Great Hall when the formwork was removed. However, we can state that the stresses caused by gravity alone would not have damaged fully hardened opus caementacium.

3.2 North-South Overturning

The north-south overturning analysis yielded some significant results regarding the present damage in the structure. At 0.26g, 1 of the 14 piers supporting the main vault underwent a critical tensile stress, with a maximum measured tensile stress of 0.54 MPa. At 0.35g, 12 of the 14 piers underwent critical tensile stresses, with a maximum measured tensile stress exceeding 1 MPa. This would cause fracture in the piers, leading to a complete structural failure as suggested by Croci et al. The magnitude of the acceleration plays a large role in the number of critically stressed piers and the maximum tensile stress. Also, a majority of the lateral arches underwent critical tensile stresses due to north-south acceleration. In the 0.26g scenario, 8 of the 14 lateral arches underwent critical tensile stress, with a

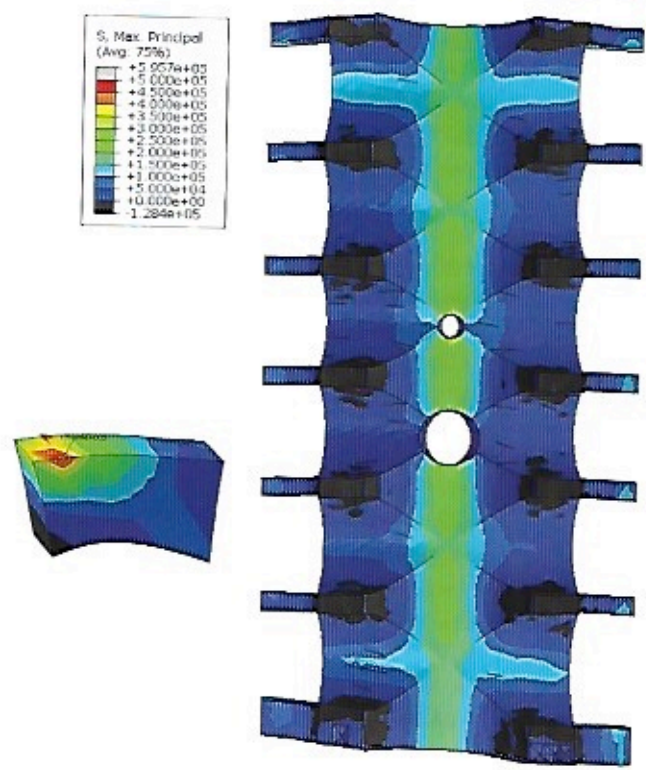


Figure 8—Gravity Stress

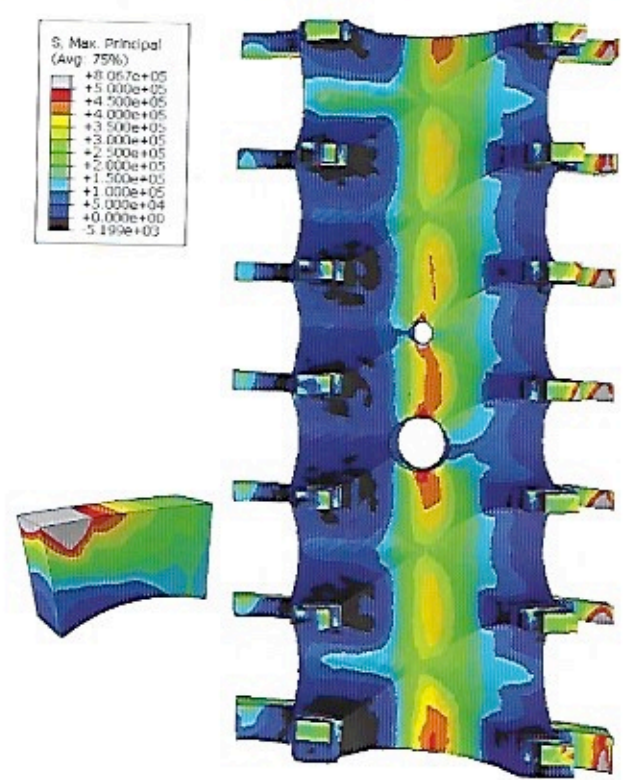


Figure 9—EW Overturn Stress

maximum measured stress of 0.78 MPa. In the 0.35g scenario, 9 of the 14 lateral arches underwent critical tensile stresses, with a maximum tensile close to 1 MPa. The stresses present in the lateral arches provide a viable explanation for the previously mentioned damage seen in the arches, which are either fractured or have been completely rebuilt.

3.3 East-West Overturning

The tensile stresses in the intrados of the main vault from the east-west overturning analysis were especially meaningful. The 0.35g test produced stresses in the middle of the intrados exceeding 0.5 MPa (Figure 9), likely causing fracture in the intrados. These numerical results correlate well with the fracture present in the intrados of vault, shown in Figure 3.

3.4 Modal Analysis

Finally, a multi-faceted modal analysis of the Great Hall was conducted in order to observe its interactions with a typical earthquake. Specifically, the natural frequency of the first north-south longitudinal mode was compared to typical north-south earthquake frequencies. First, the basic boundary conditions were used on the Roman architecture, yielding a natural frequency of 3.46 Hz. The basic boundary conditions on the Renaissance architecture yielded a natural frequency of 3.55 Hz. Next, the extended boundary conditions were used on both the Roman and the Renaissance geometries, yielding natural frequencies of 6.96 Hz and 7.11 Hz, respectively. The model architecture was then adjusted in order to more accurately depict the actual structure; specifically, a shear wall was added to the eastern vaults, and a gabled roof was cut out of the eastern extrados. Using these new architectural adjustments and extended boundary conditions, natural frequencies of 10.02 Hz and 10.07 Hz were recorded for the Roman architecture and Renaissance Architecture, respectively. The results are summarized in Table 1. The first north-south flexural mode for

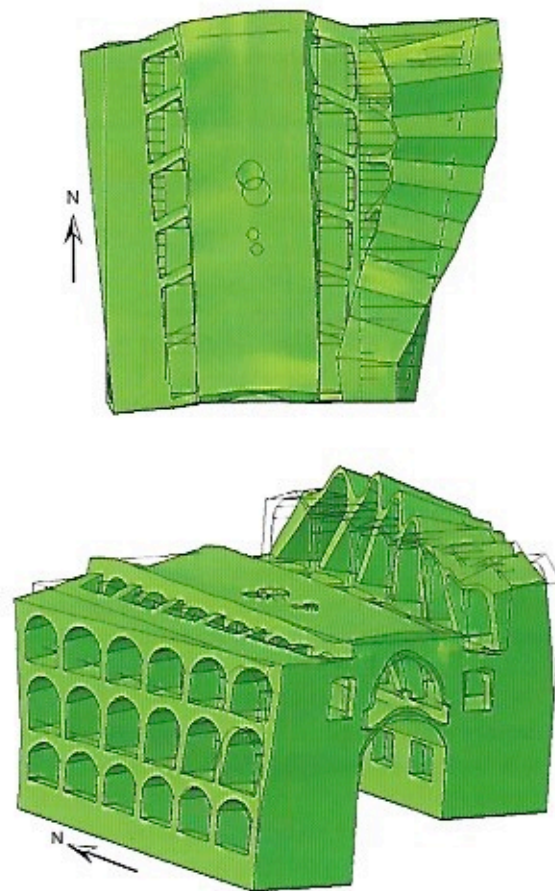


Figure 10- Mode Shapes

the Renaissance model is shown in Figure 10.

Three important conclusions can be drawn from these results. First, the Roman and Renaissance geometries show only a marginal difference in the north-south modal frequencies. Second, the extended boundary conditions greatly increase the natural frequency; in fact, the frequencies are approximately 100% higher when using the extended boundary conditions. This difference is important, and must be addressed. Third, the sheer wall significantly stiffened the structure in the north-south direction.

3.4.1 Modal Analysis with Southern Structure Architecture

Due to the difference between the basic boundary condition results and the extended boundary condition results, a different set of boundary conditions must be considered. As previously mentioned, the architecture was adjusted to include a representation of the southern structures. This provides a more realistic stiffness on the southern face of the Great Hall, falling somewhere between the zero stiffness and infinite stiffness scenarios. Using this southern structure model, the modal analysis yields a north-south longitudinal frequency of 5.40 Hz, which is significantly lower than the extended boundary condition results. This proves that the extended boundary conditions were, in fact, far too stiff.

The natural frequencies of the structure must now be compared to the prominent north-south acceleration frequencies

Model	Description	N-S flexural mode	Frequency
A	Roman configuration, basic BC	1st mode	3.46 Hz
B	Roman configuration, extended BC	3rd	6.96 Hz
C	Renaissance configuration, basic BC	1st	3.55 Hz
D	Renaissance configuration, extended BC	3rd	7.11 Hz
E	Roman configuration, extended BC, with shear walls and gables	6th	10.02 Hz
F	Renaissance configuration, extended BC, with shear walls and gables	5th	10.07 Hz
G	Roman configuration, with southern structures modeled	1st	5.79 Hz
H	Renaissance configuration, with southern structures modeled	1st	5.79 Hz

Table 1- The modal analysis results for the Roman and Renaissance architectures, using both the basic and extended boundary conditions. These results show that the architectural differences have little effect on the natural frequency (A vs. C, or B vs. D), but the boundary conditions have a significant effect on the frequencies (A vs. B, or C vs. D). The addition of the shear walls in the far eastern wall significantly stiffened the structure, thus increasing the natural frequency of the first N-S flexural mode (B vs. E, or D vs. F). As expected, the modeling of the southern structures (G and H) yields a natural frequency that falls between the basic boundary conditions.

frequencies are determined via the decomposition of an earthquake's accelerations using an FFT. The spectral analysis of a typical earthquake signal shows that the high amplitude frequencies lie between 0 and 10 Hz (Swayngim 2008). Therefore, the natural modes could likely be excited, as their frequencies also fall between 0 and 10 Hz. Such excitation could mean that a series of small vibrations create large displacement, thus leading to structural damage.

4. DISCUSSION

One distinguishing feature of the Great Hall is its asymmetry. Because it is built on a hill, the eastern half of the structure lies higher than the western half, as shown in Figure 5. In the modal analysis, the top floor of the eastern half often underwent greater displacements than any other section of the structure. In an earthquake, it would draw a disproportionately large amount of the earthquake's energy. On one hand, this would cause more damage to occur in the eastern 4th floor. This numerical result correlates well with the current damage on the 4th floor, where all vaults have collapsed. On the other hand, this mechanism would also draw energy away from other features in the structure, thus preventing damage from spreading to the main vault.

The damage in the lateral arches can be explained via the north-south overturning analysis. This suggests that typical earthquakes in the Lazio region of Italy could have caused the damage in the lateral arches via horizontal acceleration alone. Similarly, in the east-west overturning analysis, critical tensile stresses occurred along the longitudinal axis of the intrados of the main vault. These stresses could be related to the fracture observed in the vault.

Other damages, however, cannot be correlated to the present results. The collapse of the northwestern room, for example, is still unresolved. One possible explanation could be found in the excitation of a torsional mode. Because the room is in the corner of Great Hall and located far from the structure's center, it would undergo large displacements when a torsional mode is excited. These large displacements could lead to critical stresses and failure.

The Great Hall's continuing survival is a testament to the engineering ability of the Roman Empire. Although it has sustained some significant damage, the Great Hall remains largely in a state of excellent structural conservation. Important aspects of its damage state can be explained through the various analyses we conducted. In particular, the modal analysis has shown the eastern 4th floor's capability of absorbing earthquake energy. Eventually, a complete numerical investigation will require a dynamic analysis of the Great Hall, subjected to the actual time-dependant ground accelerations caused by a typical earthquake and with the opus caementicium modeled in both its elastic (undamaged) and fractured (damaged) states.

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“ROOM ENOUGH TO WONDER”: SETTING, AMBIGUITY, AND CONTROL IN SAMUEL BECKETT’S ENDGAME

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In 1984, Joanne Akalaitis directed a now-notorious production of Samuel Beckett’s *Endgame* at the American Repertory Theater in Cambridge, Massachusetts. Beckett, furious about the artistic liberties Akalaitis took with his play, tried to get a legal injunction against the production. In the end, an out-of-court settlement allowed the show to continue, but every night, audience members opened their programs to see an inserted message from Beckett himself. The message declared the production an unacceptable interpretation of his text. Beckett’s criticism centered on a single aspect of the production—the set design (Nelson).

The set of *Endgame*, as described in the original text, consists of a room with two small windows toward the back and a door on the right. The opening text of the play suggests a location with a sparse, dour tone: “Bare interior. Grey light” (Beckett 1). Whether or not Akalaitis’ set, designed by Douglas Stein, retained this tone, the imagery differed extensively from what the text dictates. The set resembled “a bombed-out subway tunnel, littered with metal beams and charred subway cars.” This wasn’t the first production of *Endgame* with an extremely different set—one production in 1983, for example, flooded the stage with murky water. Another production in 1973 housed the audience in chicken wire cages. Yet Beckett did not pursue legal action against either of these productions (Nelson), leaving us to wonder why the setting—and, more specifically, Akalaitis’ particular changes to the setting—is particularly important in *Endgame*.

Some have suggested Beckett’s particularly strong reaction to the Akalaitis set is simply the response of a tyrannical, changeable artist who expected his stage directions to be followed to the letter (Murray). However, such an argument does not just discredit Beckett but discredits the play itself. Setting plays a powerful role in *Endgame*. The play’s protagonists, Hamm and Clov, are locked in a constant struggle for dominance, and the set becomes part of their battlefield. Since Hamm is blind and immobile in his old age, he has extreme difficulty making physical changes to the set in order to demonstrate his dominance. Clov makes most of the physical

changes. Instead, Hamm attempts to intellectually control Clov’s, and consequently the audience’s, impression of the set.

Here “set” refers to more than the *mise en scène*. The setting of *Endgame* can be understood as four separate sets, or four levels of setting: the literal set, the fictional set, the metatheatrical set, and the assumed set. Each set becomes increasingly ambiguous and, as a result, further influenced by Hamm’s testimony. While Clov largely exerts physical control over the sets, Hamm exerts dialogue-driven and psychosocial control. Ultimately, many readers, notably Akalaitis and German sociologist Theodor Adorno, find Hamm’s verbal appeals highly convincing. However, it is important to note that Beckett offers viewers no certain confirmation of any setting beyond what we see onstage. Clov, who by the end of the play threatens to leave the first two levels of setting, the levels where he has the most control, and brave a world beyond his and audience’s understanding, threatens to enter a space that the characters cannot or choose not to specifically define. At the end of the play, Clov stands at the door, ready to leave but not leaving; the final line of dialogue in the play is Hamm’s commentary, “You... remain” (Beckett 82-84). The audience has no way of knowing what kind of world Clov will find outside.

By threatening to leave the set, Clov brings into question the validity of the fourth level of setting. Suddenly the audience is more curious and worried than ever about the potential truth of what lies outside the characters’ door. Akalaitis’ attempt to literalize the post-apocalyptic ideas presented in the play—ideas that together shape the fourth, assumed set—answers the viewer’s question quite easily. The audience does not need to ask what remains of the world outside of Akalaitis’ set—Clov may travel down the subway tunnels at the end; the audience can expect he will see more of the same. By contrast, the other aforementioned artistic interpretations of the set, against which Beckett did not pursue legal action, made changes that only impacted within the literal set. Even if the changes might seem even more distracting than those sanctioned by Akalaitis, they have a less important overall effect on the play, at least the play as determined by setting.

In short, Beckett's one-room literal set, a set largely removed from the American Repertory Theater's production, is integral to the play precisely because the audience remains unsure of what settings, and possibilities, lie beyond.

LEVEL ONE: THE LITERAL SET

The literal set is the only unambiguous set of *Endgame*. The set is made up of the concrete objects and lighting that the audience can perceive onstage. Beckett explains his *mise en scène* in the opening of the play. The set includes a door on the right, two small windows near the back of the stage, and grey light. There is also a picture hanging backwards on the wall, two ashbins on the left and an armchair on castors in the center. Hamm sits in the armchair, and two additional characters, Nell and Nagg, are located within the ashbins, but their presence is not immediately clear to the audience because everything is covered in sheets when the show begins (Beckett 1).

Many critics comment on the dire atmosphere created by the literal set. In the *New York Times* review of *Endgame*'s American premiere, Brooks Atkinson more or less repeats Beckett's prescribed set design, modified with depressing adjectives. He calls the set, "a gloomy brick cavern with spectral light, two grotesque windows that can be reached only by a ladder, scabrous walls, rubble, decay" (Atkinson). Beckett scholar Katharine Worth speaks of the literal set's claustrophobic and sparse nature. She writes, "There is an oppressive impact from the unvarying grey light and the refusal of ordinary comfort" (Worth 36). Similarly, Shimon Levy draws a connection between the covered objects that fill the closed, interior set and the way characters discuss their bodies. He writes, "body and heart are also described in terms of closed space: 'last night I saw the inside of my breast'" (Levy 23). Clearly the first set has an important visual and thematic impact. The first set also includes an extreme irony, since the gloomy space is meant to be the central room of a house, a family room, which now perpetuates a twisted sense of family through the characters who operate within its scabrous walls (Worth 36).

Hamm calls the house "my house" (Beckett 36), and since Hamm remains immobile and blind throughout the play, he is forced to remain within one room. However, it is Hamm's very immobility that gives Clov ultimate control of the literal set. Clov is the only character who may move about the environment unassisted and who can assert physical changes on the environment, such as uncovering the objects onstage in order to begin the play (Beckett 1). Clov is the only character who moves through the onstage door and the only character who can reach the windows via a stepladder in order to look out the windows first-hand. Clov never chooses to show the audience the face of the picture facing the wall, though doing such would easily be within his power. In fact, this example of a continued unknown parallels the effect of the higher-level sets throughout the play. Clov never turns the picture around to reveal the image, and he never leaves the immediate house to reveal the world outside. Thus, the imagery of the literal set demonstrates Clov's ultimate control of the set.

However, the house still officially belongs to Hamm. At one point Hamm tells Clov, "my house [was] a home for you," and Clov agrees (38). Hamm forces an acknowledgement that Clov

is able to operate within the set, qualified by the past tense, even as Hamm insists upon his ultimate ownership of the space. Such insistence continues over the course of the play. Charles R. Lyons describes the set as a prison for Clov since Hamm constantly commands Clov inside the room. Lyons writes, "The image of master and slave subsumes the image of space" (Lyons 55). While the space does serve as a prison in a way, Hamm's extreme authoritative action within the literal set may be read as an attempt to assert control where he is essentially powerless. Hamm can order Clov to move him around the set, for example, or fetch him props, but Clov can just as easily make unannounced physical changes to the set.

One such moment of agency occurs when Clov starts cleaning the area without any order to do so. Though Hamm can physically change the space by throwing objects Clov offers him, Clov has the ultimate control because he can clean up the space as a counteragent to Hamm's self-imposed chaos. Clov goes so far as to play off the idea of being ordered; twice Hamm asks what Clov is doing, Clov responds first that he is "putting things in order," second that he is "doing [his] best to create a little order." "I love order," Clov says. "It's my dream" (Beckett 57). In this quote, Clov seems to mock Hamm's limited control—not only is he taking unauthorized physical control of the set, he repeats the word "order" so as to belittle Hamm's limited power over him and appropriate the term for his own, with his own meaning. In contrast to Hamm's orders, Clov's order makes sense and is decided upon his terms.

In an attempt to counteract his limited physical ability within the set, Hamm questions the relevance of the set itself. In the play, Hamm asserts control by instructing Clov to move him around the room and, eventually, to situate him in the precise center of the stage. Even before Hamm resumes the center of the room, he makes two accusations about the wall. He touches the wall, finally making physical contact with his own house. He says, "Beyond is the...other hell" (26). This elusive, doom-laden statement evokes the imagery Hamm uses to create the fourth set; it plays off the audience's utter inability to know what is beyond the wall. As a result of this inability, the claim maintains mystery and strength that distracts the viewer, and likely Clov, from the immediate literal set by prioritizing the unknowable set outside of the house.

Hamm goes on to strike the wall. He says, "Do you hear? Hollow bricks! All that's hollow!" (26) This is a highly theatrical gesture on Hamm's part. If he has lived in the house for years, as implied, he very well ought to know whether his walls are hollow or not. Therefore, his actions are a performance for Clov and the audience, rather than an evocation of actual shock. Whether or not Clov "hears" or agrees, Hamm's appeal is likely to appeal to the theater-goer, who knows that the wall of the room may very well be hollow. Hamm questions Clov about the issue, but in effect he speaks to the audience, as the metadrama reminds and thus counters the audience's suspension of disbelief. Hamm clearly breaks from Beckett's beliefs—though Hamm may call the wall hollow in order to minimize its narrative importance, Beckett placed the wall on set for a specific reason. It seems very possible that this reason is that he wishes the audience to question the validity, and possibly the dramatic importance, of Hamm's claims. Hamm's claims, no matter how effective, do

compelling claims. In the end, Clov retains ultimate practical control of the first set.

LEVEL TWO: THE FICTIONAL SET

Beckett's commentary and visual clues renders the second set, the fictional set, easy to imagine and likely real within the narrative of *Endgame*. The set is still slightly ambiguous because it is inherently available to subjectivity—the fictional set consists of locations the audience cannot see but still exist as an immediate extension of the on-stage world. The set, a conflation of interior and exterior, refers to the kitchen space and the outside view as seen through the windows in the room. Though these sets are only available to the audience through narration, visual cues in the literal set, namely the door and windows, lend credibility to the characters' claims about the sets. Hamm and Clov generally agree about the logistics of interior kitchen, but Hamm constantly questions Clov's reports of what exists beyond the windows, calling attention to the subjective nature of the fictional set as a whole.

If Hamm owns the room of the physical set, the kitchen is characterized as Clov's domain. This is established within the first speech of *Endgame*. Clov says, "I'll go now to my kitchen, ten feet by ten feet by ten feet, and wait for him to whistle me" (Beckett 2). From the start, Clov claims ownership of the kitchen and suggests that Hamm normally whistles because he expects Clov to be in the kitchen. Clov offers the audience concrete dimensions that lend credibility to the fictional space and help the audience imagine the space. Moreover, Beckett himself confirmed the existence of a kitchen multiple times. An early manuscript of *Endgame* focuses entirely on Clov's—then known as F—attempts to escape to the kitchen (Lyons 51), and later, Beckett said that one of the main tensions of *Endgame* is Clov's struggle to return to the kitchen as Hamm attempts to keep him in the main room (Worth 83). Indeed, Clov retreats to the kitchen multiple times over the duration of the play. Clov's focus on the kitchen is somewhat rebellious in nature. The kitchen belongs to Clov because, as a servant, he can use the space to prepare meals for Hamm. Yet the space also offers Clov partial ownership of Hamm's house and limits Hamm's overall claim to his home.

Clov appropriates the kitchen, a place of service where he could cook for Hamm, as a sanctuary free of Hamm. Worth emphasizes the importance of Clov's kitchen, calling it "his great advantage over Hamm." She cites the fictional status of the kitchen as part of its strong narrative power. She writes, "We know we will never see into that mysterious space where Clov looks at the wall and sees 'my light dying.' It sounds grim yet might suggest the possibility of change; the dying of a light as a prelude to a new day" (Worth 83). Clov's escapes to the kitchen arguably foreshadow his eventual escape to the outside world.

The audience, and Hamm, receives key information of this outside world through Clov's reports of what he can see through the two windows of the set. Clov claims there is land on one side of the house and the ocean on the other (Beckett 27-30). Hamm agrees with this information, but he argues with Clov on more precise conditions. When Hamm asks Clov to describe the sun, for example, Clov answers "Zero." Hamm replies, "But it should be sinking. Look again." Clov's

revised assessment is elusive—"Damn the sun" (31). This final thought offers little information about the state of the sun, when Hamm and the audience both rely on Clov for information of the outside world. Clov's reports of the world outside are subjective, at times elusive and always potentially false. As Lyons writes, "The gap between the landscape outside the windows and Hamm's consciousness cannot be bridged," and this throws all of Clov's claims about the outdoors into question (63). As such, the windows, like the kitchen, provide Clov a means of defying Hamm.

The audience and Hamm rely equally on Clov's reports of outside, and the kitchen is specifically Clov's domain. As a result, Hamm's attempts to control the fictional set are all addressed directly to Clov, as opposed to his attempts to control the literal set, which resonate more deeply with the audience. Hamm responds to the fictional set much as he responded to the literal set. That is, he does everything in his power to undermine Clov's control over the set. Hamm questions what Clov plans to do in the kitchen. Clov explains that he looks at the wall. Hamm responds, "The wall! And what do you see on your wall? Mene, mene? Naked bodies?" Clov explains that he sees his light dying, to which Hamm retorts, "Your light dying! Listen to that! Well, it can die just as well here, your light" (12). Hamm mocks Clov's activities, exaggerating what Clov might see on the wall by calling it a potential portent of doom or a crude hallucination of naked bodies. Though Worth describes Clov's observation of his light as a hopeful activity (Worth 83), Hamm speaks of it as if it is a ridiculous idea. Underlying Hamm's mockery is an attempt to keep Clov from leaving the main room. Hamm's mockery attempts to prevent Clov from accessing a set where Clov exerts control.

Similarly, Hamm attempts to interpret and redefine what Clov sees through the windows. As seen in the aforementioned quote about the sun, Clov can easily circumvent any claim Hamm makes about what the windows should or shouldn't depict. As a result Hamm resorts to mocking Clov's reports. When Clov reports that the light is gone, Hamm responds "Pah! We all knew that" (Beckett 30). It is telling that Beckett describes Hamm's response as "relieved." He is pleased when Clov confirms what he expected to hear, in part because the outside world seems to match his expectations, but also because by expecting such a result, Hamm maintains some level of control in the view from his windows though his correct knowledge of the world. Of course, either Clov or Hamm (or both) could easily be lying about what they have seen and expected to see outside the window. Regardless, Hamm attempts to minimize Clov's power to determine the immediate outside world, the fictional set, by suggesting that Clov's observation was unnecessary and unhelpful. In general, Hamm presents his weakest defenses against Clov when attempting to take control of the fictional set. Clov's ability to move combined with the need for eyewitness accounts in order to confirm what cannot be seen by the audience allows Clov the ability to define and dominate the fictional set.

LEVEL THREE: THE METATHEATRICAL SET

If the fictional set is largely dependent on Clov's testimony, the metatheatrical set is largely dependent on the existence of an audience. On some level, the audience is always aware that they are observing the fictional, artificially constructed

setting of *Endgame* in the real-life setting of a theater. At the same time, theater requires a suspension of disbelief where audience members are asked to forget that they are watching a performance on a stage. Though all plays have a real-life setting, only some plays break the suspension of disbelief in order to call attention to, and draw distinctions between, the real and the fictional. Naturally, the characters in *Endgame*, especially Hamm, strive to control every possible set; it is not surprising that the play is peppered with metatheatrical references that suggest the characters' control of the audience through their connections with the real-life world.

In a way, the metatheatrical set is still more ambiguous than the fictional set. At least both characters and the literal set confirm the existence of a fictional set within the fictional world of the play. Aside from references to theater and the rare stage direction that a given speech should be delivered to the audience, the characters never outright acknowledge the metatheatrical set. The metatheatrical references constantly bring into question the extent to which the characters are aware of the audience. Does Hamm acknowledge the audience in his metatheatrical references or merely theater itself? Regardless, Hamm's metatheatrical references do engage the audience in a way that gives him control of the set and, to an extent, control of the audience.

Hamm makes a number of comments about play-acting, famous plays in the theatrical canon, and theatrical conventions. Hamm's first line in *Endgame* is "Me (he yawns) to play" (Beckett 2). The verb "play" is ambiguous; Hamm could be declaring that he will play a fictionalized role, or he could simply be declaring his intent to participate in some sort of game. Either way, it is an acknowledgement that he is an active participant in a constructed environment. As his first line it suggests his character has been newly created for some sort of artificial purpose. His yawn ironically underscores the enormous significance of such an admission, but his potential self-awareness and the way his line resonates with the audience, who knows he is already playing, gives him some control of the metatheatrical set.

Another metatheatrical moment occurs when Hamm cries out, "My kingdom for a nightman!" (23). The moment recalls Richard III's famous line, "My kingdom for a horse!" at the climax of Shakespeare's play. However, in *Endgame* the line carries a very different tonal feel, since a nightman is someone who empties toilets at night. In the original text, Richard is calling for a horse before he dies in battle; in fact, the line is the character's final piece of dialogue in the play. Hamm's rewritten version of Richard's request is hyperbolic and humorous. Hamm will not die if he does not obtain a nightman, and the line is certainly not his last in the play. The reference to Richard III encourages the audience to compare Richard and Hamm. This is a particularly interesting comparison, since Richard was a tyrannical king who murdered those who prevented him from obtaining and maintaining the throne. Hamm is accused of allowing the unnecessary death of Mother Pegg, a character mentioned a few times in the text (75). Moreover, Hamm certainly holds a tyrannical position in the household, ordering Clov around and shutting his parents (Nell and Nagg) in ashbins. It is unclear whether Hamm or Beckett wishes the

audience to draw such connections. More importantly, Hamm's manipulation of a famous Shakespearean line suggests an awareness of Shakespeare's work and a potential awareness that he, like Shakespeare's Richard, is a character in a play. This knowledge gives Hamm control in the metatheatrical set, and Hamm exercises further control by modifying the original line to undermine the original dramatic significance and potency. If Hamm is consciously performing, modifying the line suggests an impressive ability to control his performance.

Finally, Hamm's references to theatrical conventions allow him to mock audience expectations. Seven pages from the end of the play, Clov claims to see a boy approaching the house. Hamm responds, "More complications! Not an underplot, I trust" (78). Even if the audience is unsure how much longer the play will continue, they will likely be aware that it is far too late in the play to introduce and develop an underplot. As a result, Hamm's statement plays off the audience's expectations about what might happen in the remainder of the play. In this context, his line functions as both audience commentary, since viewers may very well be thinking the same thing, and as a threat to the audience, since an onstage character asking if an underplot will unfold suggests Beckett was considering an underplot at this point. As a result, Hamm's metatheatrical comments also allow him psychological control over the audience.

Hamm's theatrical flourishes hint at Hamm's constant insistence on his theatrical value. Levy writes, "Hamm consciously refuses to peel off his 'actor' role. Not only Clov, his main audience, but his parents also...are a nervous, unwilling audience sick of playing the audience role" (Levy 96). As such, Hamm tyrannizes the other characters with his performance. His performance as a character in the drama is deliberate, if not voluntary. Jonathan Boulter characterizes Hamm's metadramatic activities as villainous, an "almost maniacal manipulation of details" where Hamm "looks like he is attempting to assert a creative, existential autonomy" (Boulter 50). Boulter's use of "almost" and "looks like" suggest the ambiguous nature of the metadramatic set—it is impossible to know if Hamm's activities come from a metadramatic self-awareness—but it seems highly likely.

It is important to note that Hamm does not hold monopoly on metadrama in the play. Clov makes a few metadramatic comments of his own. The most important example occurs at the very end of the play. Clov prepares to leave Hamm's house, and as he goes to the kitchen to gather his things, Hamm attempts to stop him from leaving. Clov "halts, without turning" and responds, "This is what we call making an exit" (Beckett 81). The moment demonstrates an awareness of his dramatic flair, and the line resonates with the audience and Hamm because both parties likely presume Clov's exit will be his final appearance in the play. However, Clov returns shortly with his things, prepared to say final goodbyes before he makes his real exit. As a result, the line plays on audience expectations in a way that suggests an awareness of the audience. Even more significant, though, is Clov's awareness of Hamm's metadramatic activities. He says, "this is what we call making an exit," suggesting that both he and Hamm have the awareness needed to control the metadramatic set. It seems fitting, then, that this line is Clov's last in the entire play. In the end, Clov

seems to gain Hamm's ability to play upon and manipulate the metadramatic sphere, threatening Hamm's control of this level of the set in the final moments of the play.

LEVEL FOUR: THE ASSUMED SET

Arguably the most compelling setting in *Endgame* is also its most ambiguous. The play is littered with gloomy hints of what lies beyond the first three sets and the current state of society. These hints come in three categories: nostalgic comments about nature, remarks highlighting limited resources within the house, and ambiguous statements about what exists beyond the house. Importantly, most if not all of these hints originate from Hamm.

The hints can be cobbled together to construct a dark, post-apocalyptic version of the world. In terms of ambiguous statements, Hamm states, "Outside of here it's death" (9). He repeats the statement near the end of the play, except the second time it is punctuated with an exclamation mark (70). This might not seem like a terribly ambiguous statement, but it is unclear whether the death Hamm describes is literal or metaphorical, past or current, and referring to death of people or the death of the environment. Though the statement is effective in its shockingly blunt nature, it does not offer the audience any concrete information. In another example, Hamm says, "Imagine if a rational being came back to earth, wouldn't he be liable to get ideas into his head if he observed us long enough" (32). He then proceeds to imitate the "rational being" for Clov. This statement is ambiguous not for any lack of specificity but because it is presented as a joke. While it's possible that humans have abandoned the planet and all live in space in the universe of *Endgame*, it seems far more likely this was meant as a joke.

Another way in which Hamm—and Clov—perpetuate the idea of the assumed set is through discussions of limited resources available. Though in most cases this refers to a lack of food (6, 55, 56, etc.), one particularly striking example occurs when they discuss their lack of bicycle-wheels. Clov waxes poetic, "When there were still bicycles I wept to have one. I crawled at your feet. You told me to go to hell. Now there are none." Much like the line about rational beings, there is something hyperbolic, even bitterly funny, about this declaration. Both Clov and Hamm act ridiculously in the anecdote—Clov crawling, Hamm cursing Clov to hell—to an extent that one could interpret the line as parody or metaphorical. The lines about a lack of food are far more convincing and compelling. However, Lyons cleverly points out that at one point in the play, Clov says he only speaks the words Hamm taught him. This statement throws many of Clov's lines during the play into question (Lyons 65). Clov could be lying, or simply misinformed, when he discusses the food shortage.

The final set of hints Hamm drops about the assumed set are nostalgic comments about nature. Hamm seems to characterize the world beyond the literal house as an environment utterly lacking nature. Hamm and Clov discuss the topic:

HAMM: *Nature has forgotten us.*

CLOV: *There's no more nature.*

HAMM: *No more nature! You exaggerate.*

CLOV: *In the vicinity.*

(Beckett 11)

Ironically, this quote seems to label Clov as the character

insisting on a lack of nature. However, the audience cannot trust anything Clov claims as truth, since he might be parroting Hamm's opinions. Moreover, Clov does not begin to comment on nature until Hamm begins the conversation. The quote displays a constant effort to define and re-define the characters' beliefs about nature, suggesting much uncertainty. Finally "nature" is an elusive term here and could even refer to human nature rather than the natural world. This elusiveness can also be seen in a poetic waxing on the subject. Hamm fantasizes, "I'd go into the woods. My eyes would see... the sky, the earth. I'd run, run, they wouldn't catch me" (18). This quote can either read as a contradiction to the idea that nature is gone, or it can be read as an impossible fantasy for a world long gone. This latter reading is encouraged by Hamm's ability to use his legs in the fantasy, when the speaker is clearly and permanently located in an armchair as he delivers the lines. If nothing else, these examples prove that the question of any potentially remaining flora or fauna is very much a part of Hamm and Clov's everyday life and typical conversations.

Put together, these little hints and others like them form a dark image of a post-apocalyptic world that exists beyond the literal set. However, it is important to remember that the characters never officially confirm the assumed set (hence its label). Boulter points to a story Hamm tells about the world beyond the literal set. The story is full of poverty and desperation, but Hamm begins with specific descriptions of the weather conditions in which the story takes place. According to Boulter, the insistence upon specific details represents Hamm's attempt to control all aspects of the story (Boulter 46). At another point in the play, Hamm tells the story of a friend in an insane asylum. Hamm explains, "I'd take him by the hand and drag him to the window. Look! There! All that rising corn! And there! Look! The sails of the herring fleet! All that loveliness!...He'd snatch away his hand and go back into his corner. Appalled. All he had seen was ashes" (Beckett 44). This story shows the potential for characters who interpret their world subjectively. Andrew K. Kennedy writes, "It is not clear whether Hamm's vision is identical to that of the madman who thought the end of the world has to come (Kennedy 52). Kennedy's analysis implies, however, that even if Hamm's vision differs from that of the madman, the anecdote still demands the audience to contrast Hamm's discussion of nature with the madman's potentially mistaken ramblings. It is also possible that the madman understood a greater truth than Hamm at the time of the anecdote. The only thing careful readers of the text can know for certain is that Beckett does not offer the audience enough information to know whether or not the post-apocalyptic or dystopian suggestions are meant as entirely true, true as metaphor, or entirely false.

The assumed set appeals to many critics, which only goes to prove that Hamm is extremely successful in his attempt to control the fourth level of setting in *Endgame*. The assumed set certainly inspired the American Repertory Theater's set. Akalaitis' New York subway tunnel and industrial litter attempted to show a world after a bombing had taken place (Nelson). As Hamm spoke of death outside and Clov spoke of "no more nature," the audience could stare at char marks on the walls and attach a literal, likely political significance to the character's

claims. Similarly, Adorno read *Endgame* as an extended metaphor for a post-apocalyptic, perhaps post-Holocaust society. He writes, "The condition presented in the play is nothing other than that in which 'there's no more nature.'...Indistinguishable is the phase of completed reification of the world...it is permanent catastrophe...in which nature has been extinguished and nothing grows any longer." (Adorno 122-123). Adorno completely accepts the assumed set as the truth and basis of the play. Kennedy claims the apocalyptic reading is both compelling and accessible. He writes, "The chess analogy does not work concretely or with any particular force. The metaphor of cosmic extinction probably finds a response in a great number of people." He cites a potential collective understanding of the end of the world, the role of the apocalypse in early mythologies, and modern nuclear war scares (Kennedy 53). The apocalyptic, or post-apocalyptic, reading of the play has received critical acclaim.

By contrast, Lyons bluntly states, "The objective fact of the external world has no real significance in the play" (Lyons 63). I am inclined to agree. No matter how compelling, Beckett reminds us that the fourth set of the play is, in fact, assumed, made up of subjective stories and metaphors, without any concrete facts or evidence. Evan Horowitz argues that the play is based more around uncertainty than apocalypse. In his article "Endgame: Beginning to End," he analyzes the final moments of the play. Clov claims he will leave Hamm. He appears onstage "dressed for the road" (Beckett 82) but as the lights dim and the play concludes, he remains by the door, watching Hamm. It is very likely Clov is reluctant to leave because of his understanding of the world outside. He has been told outside is death, a place that may not withstand human survival. Adorno might have considered Clov's exit suicidal. However, Horowitz points out that the ending of the play is shrouded in uncertainty. He writes, "In the end, we fear two things: that Clov will never leave and that Clov will leave (and find nothing). Between those alternatives there is no room for hope, but there is room enough to wonder" (Horowitz 127). There is also a third, unacknowledged alternative—Clov might leave and find Hamm has exaggerated the state of the world outside of his house. This ending seems highly unlikely given the themes of death and loneliness present throughout the play. However, it is important to remember that the third possibility remains, even if Beckett does his best to make the viewer forget that fact. Moreover, Clov's goal is not happiness so much as freedom. Horowitz writes, "The only way out of Hamm's game of death is death, or rather a retreat to that outside which Hamm calls death. For Clov, the end represents not only a space of termination but also a space of possibility" (124). The ambiguity of Beckett's fourth set allows for such possibilities, and Hamm's visible struggle for control over the previous three sets allow viewers to recognize the ambiguities of the fourth set, no matter how convincing it may seem.

In conclusion, the setting of Beckett's *Endgame* operates on four different levels. Hamm and Clov battle for control of each level, and Clov's final threat to abandon the first three sets and brave the highly uncertain fourth set forces the audience to imagine the fourth, assumed set and to hypothesize about whether Clov will survive—and whether he will actually leave.

Akalaitis' production was not the first and will not be the last production to diverge from the exact text of Beckett's play. New iterations and incarnations of plays are an integral part of theater. However, deeper analysis of the role of set in *Endgame* offers a potential explanation for Beckett's outcry at the particular deviations in Akalaitis' set. Akalaitis' changes question what Beckett wanted to leave for the audience. Set changes are a director's prerogative, but it helps if a director understands the full impact of the changes they make to the text. One wonders if Akalaitis was fully aware of what she was cutting from *Endgame*—and what she added. In deviating from Beckett's vision, she inevitably created something new and unique. She also, inevitably, failed to represent the story Beckett chose to tell.

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mRNA KINETICS: REVISITING FITNESS IMPLICATIONS OF SYNONYMOUS MUTATIONS

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A theory is a simplified model that allows computation in a complex reality with relative simplicity at the expense of irrelevant factors. In the theory surrounding evolutionary fitness, synonymous mutations have been disregarded as irrelevant factors. Synonymous mutations are genetic mutations which do not affect the polypeptide chain yet produce distinct mRNA. The irrelevance of synonymous mutations, due to their proteomic equivalence, predates a greater understanding of the transport of mRNA from transcription to translation. Recently, studies regarding mRNA folding and stability, translational kinetics, and RNAi activity have provided new mechanisms that may transduce fitness without affecting the polypeptide chain. The relevance of pre-translational mRNA kinetics is relatively new and involves the activity and phenotypic transduction through direct, pre-translational mRNA interactions. This paper explores the plausibility of synonymous mutations affecting fitness and subsequent selection as well as the semantic interpretation of relative synonymous mutation levels. In this study, each of these mechanisms is shown to have dramatic phenotypic results without affecting their respective polypeptide chains. In addition, relative synonymous mutations are shown to affect relative fitness. Relative fitness associated with relative amounts of synonymous mutations is further evidence for an entire world of meaning within allegedly irrelevant mutations.

DEFINING SELECTION AND FITNESS FOR SYNONYMOUS MUTATIONS

Fitness is the probability of propagating a genotype. More specifically, it is directly proportional to lifespan, maturation time, aptitude in mating and courtship, and number of offspring (Orr, 2009), which must be considered relatively on a population scale (Crow, 1970).

With this definition of fitness, it is also important to consider the transducer of fitness: selection. Selection takes into account relative population size (Ohta, 1977) and then scales fitness accordingly by the number of possible genotypes and their relevant combinations, as well as each gene's relative fitness (Hartl, 1981).

In "Nearly Neutral Evolution," Ohta established the possibility

of selection of mutations with minimal selection pressure, such as that of synonymous mutations and the possible proliferation of minimally deleterious mutations given large population sizes, therefore allowing for the proliferation of various synonymous mutations (Ohta, 1976; Ohta, 1992). Recent estimations claim the effective population size of mammals such as humans is four individuals (Sharp, 1995), which, according to Ohta's Nearly Neutral Theory, would result in strictly insensitive fitness selection. Hence, synonymous mutations must have a profound effect on fitness in order to fit the current model and have a noticeable effect on selection. An analogous situation is that of multi dimensional graphs. When too many dimensions are incorporated to calculate one value, small and even moderate changes in individual dimensions are lost to the complexity of the system. This is best visualized in "high" dimensional fitness landscapes (Wright, 1931). When a large number of dimensions are incorporated, small changes in one allelic dimension are nearly insignificant, and this insignificance translates well to evolutionary selection under the model of Nearly Neutral Theory.

Gene	Nonsynonymous rate	Synonymous rate
Histone H4	0	3.94
Histone H2	0	4.52
Ribosome S17	0.06	2.69
Ribosome S14	0.02	2.16
Hemoglobin alpha	0.56	4.38
Hemoglobin beta	0.78	2.58
Myoglobin	0.57	4.10
Interferon gamma	3.06	5.50
Interferon alpha	1.47	3.24
Interferon beta	2.38	5.33

Table 1 Respective rates of synonymous and non-synonymous mutation organized by gene. Histone H4 and H2, which are core elements to the crucial task of chromosome folding and are subsequently highly conserved, have no non-synonymous mutations but still some synonymous mutations. For interferons, the Dn and Ds levels are relatively high. These rates are a direct response to specific environments and protect the organism on a cellular level. (Clegg, 1991)

REFINING SYNONYMOUS AND NON-SYNONYMOUS MUTATIONS AND THEIR RESPECTIVE FITNESS AND SELECTION RATIOS

Synonymous mutations are defined as DNA mutations that result in codon substitutions which preserve the amino acid sequence of the subsequent polypeptide. Their counterpart is a non-synonymous mutation. Non-synonymous mutations are DNA mutations that result in codon substitutions which do not preserve the amino acid sequence of the subsequent polypeptide. Synonymous mutations were previously presumed under neutral theory to be selectively neutral, while Non-synonymous mutations, those which actually change the resulting protein, are either mostly lethal or rarely beneficial (Kimura, 1977). Although the idea of neutrality provides an important scaffold for the unfolding of subsequent

It measures the proportion of nonsynonymous mutations compared to the proportion of synonymous mutations; the proportion is the measure of substitution that occurred over the number of sites where these substitutions may occur. A high ratio corresponds to highly adapting structures while a low ratio corresponds to a well-adapted structure. The Wright-Fisher model (Nelson, 2003), which presents the math surrounding the ratio, assumes that the sequences being compared originate from long divergent structures. In this situation the Dn/Ds ratio refers to mutations defining this divergence. Recently, Dn/Ds ratios have been used in the comparison of sequences within populations. In this comparison, the Dn/Ds ratios signify polymorphisms instead of mutations. This results in incorrect predictions from the Wright-Fisher model which was built to describe alternate circumstances; the developing model must involve some combination of the fixation equation and the single population analogue Dn/Ds equation, therefore making the relevant variables to Dn and Ds mutation effects on fitness and subsequent selection dependent on N, s, and μ where N = population, s = fitness and μ = mutation rate.

The relevant factors of Dn/Ds which affect selection pressure are therefore: population size, selection coefficient, and mutation rate (Kryazhimskiy, 2008). Population size is addressed in the discussion of Nearly Neutral theory. Selection coefficient is an artificial calculation produced by the degraded model and is therefore likely the source of error. Mutation rate is a biological constant. Thus, the only relevant variable in the transduction of Dn or Ds to selection is population size, as stated in Nearly Neutral theory.

A low Dn/Ds ratio is typically characterized by a low Dn and high Ds (Mouchiroud, 1995). Histones are paramount proteins that are highly conserved and show very low Dn/Ds ratios. This reflects the crucial nature of maintaining the structures of these elements to preserve function due to their central role and environmental irrelevance (Table 1). Therefore, given conclusions which can be made based on the ratio and the correlation between the two substitution rates (Mouchiroud, 1995), the ratio should be decomposable into a discussion of Dn and Ds effects on fitness. The original construction of this ratio was intended to normalize Dn to Ds, a hypothetical representative of the rate of neutral mutation (Drake, 1991; King, 1969). But with the surfacing of evidence supporting Ds relevance to fitness, it may be important to discuss Dn and Ds separately. Alternatively this may simply be confounded by the correlation between these two variables.

FITNESS MODULATION OF SYNONYMOUS MUTATIONS EFFECT ON SELECTION

Synonymous mutations are mutations to DNA that do not change the polypeptide chain, because multiple codons are known to map to single tRNAs. Intuitively, this would seem to have no significant effect on the organism since nothing has changed about its proteome. Yet, this is not necessarily true. Understanding the process of moving an mRNA from the nucleus to the ribosome is becoming an increasingly complex subject. There are more and more ways of moving an mRNA being discovered, indicating that mRNA may affect the phenotype and subsequently the fitness of an organism in transit from transcription to translation, regardless of whether its subsequent polypeptide is altered. The mRNA may be modified in such a way that affects its mRNA stability, splicing, RNAi interactions and exon splicing, translational stalls and subsequently protein folding or chromatin folding (Hurst, 2009; Parmley, 2007; Charnary, 2006).

A synonymous mutation could easily affect the mRNA stability. There are many endogenous cellular elements capable of mRNA degradation: RNA is a relatively unstable construct due to the oxygen on the 2nd carbon of the ribose sugar which has the potential to attack the proximal phospho-diester bond. RNases and endonucleases are produced specifically to identify malformed mRNA and degrade it. This instability is depicted in Figure 2. One way to increase stability is to increase the number of GC bonds in the structure, thus increasing the strength of bonds and the general fortitude of the mRNA structure (Kozak, 1988). There are multiple observed cases wherein the amount of mRNA reaching the ribosomes is correlated with mutations from GC \rightarrow AU bonding in the mRNA secondary structures. Dopamine Receptor D2 (DRD2) has six observed mutations of this nature. As expected, replacing the GC bonds with weaker AU bonds decreases the stability of the molecule, enabling spontaneous mRNA degradation and RNase

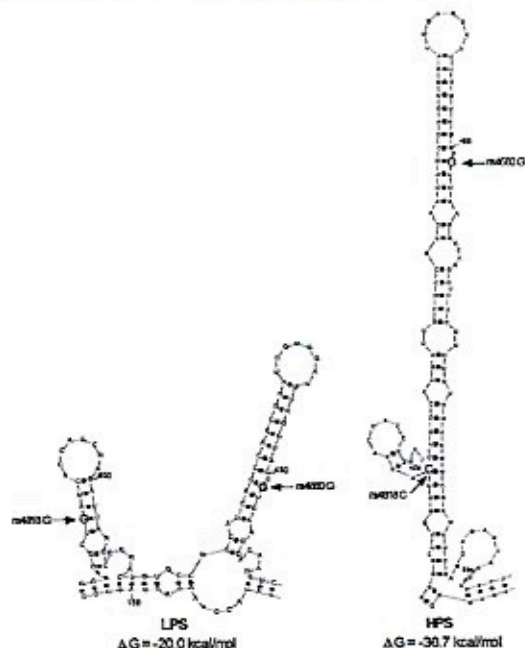


Figure 1 - The Predicted structures of the LPS and HPS haplotype mRNAs and their Gibbs free energy (ΔG). Note that these two extreme haplotypes differ only at the synonymous rs4818 SNP and not at the non-synonymous rs1680 SNP (courtesy of Andrea G. Nackley Neely).

Deregulation of pain can often be deleterious. Too little pain can leave the organism susceptible to harming itself by neglecting its wounds, while too much pain can be debilitating. Hence this mutation has selective relevance.

Another relevant susceptibility of mRNA that may be affected by synonymous mutations is RNA interference interactions. This is because much of the initial understanding of these interactions was of a self regulation intrinsic to the gene. The RNAi was produced by the antisense region of the transcription of a portion of the mRNA and so was only relevant to its sister mRNA (Beltran, 2008; Katayama, 2005). In this model, mutations of any type are irrelevant, as a mutation in one molecule will be reflected in the antisense transcription. Recently, evidence has begun to surface implicating

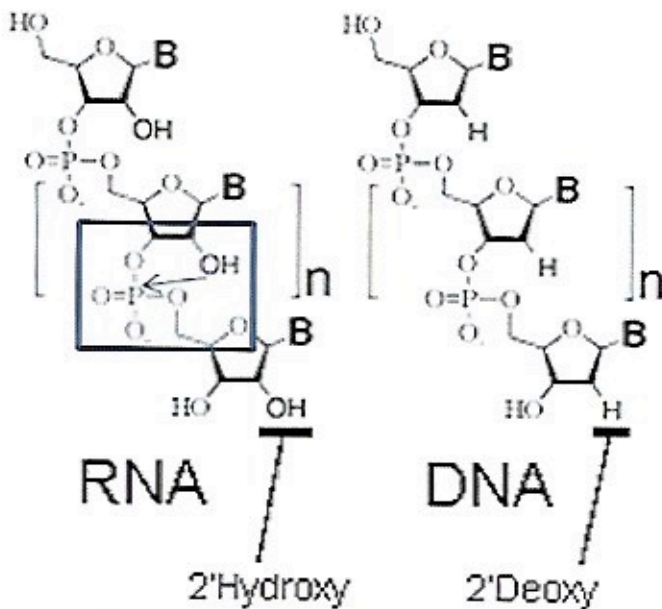


Figure 2 - Three nucleotide chains of RNA and DNA. The 2' Hydroxy and 2' Deoxy is pointed out on the third nucleotide and the 2' Hydroxy "attack" is illustrated between the 2' Hydroxy on the 2nd nucleotide and the phospho diester bond joining the 2nd and 3rd nucleotides

RNAi in many extrinsic interactions with regulatory implications on a whole cell level. In bacteria and archaea, the CRISPER/Cas System of cellular defense has recently been discovered and is starting to take shape. The system incorporates fragments of foreign cDNA into the host genetic code by employing short interspaced palindromic sequences in the DNA. These sequences allow for the incorporation of foreign cDNA; it subsequently transcribes miRNA to interfere with the potency of later infections. The direct action of this defense does not actually require the translation of the documented invading cDNA; instead, the defense is simply its antisense counterpart (Karginov, 2010).

During the study of this system, an experiment induced a single synonymous mutation to a section of a palindromic sequence. This effectively inhibited the ability of the palindrome to facilitate the complex folding mechanism that allows incorporation of foreign cDNA into the genome (Marraffini, 2008). An experiment of a different nature investigated the question of RNAi's potential for general post-transcriptional regulation. Known small RNA sequences were compared within a set of genes translated via or-

thological comparison from the human to the mouse genome. The study revealed antisense alignment between the coding sequence of the genes and the miRNA. This means miRNA is capable of both endogenous and exogenous cellular level regulation (Ilurst, 2006). The evidence strongly suggests that genetic elements of the non-proteomic phenotype whose expression and function are dependent upon complex DNA folding will be heavily affected by any genetic mutation: synonymous or non-synonymous. Clearly, immunology is a deciding factor in survival time; therefore this specific case also influences fitness.

In a similar manner, nucleotide folding complexity crucially affecting the phenotypic action of a gene can be seen in the genetic hardware for exon definition. It is easy to assert the massive complexity and sequence dependency of the effective operation of splicing machinery. But to be more specific, there are identified structures worth investigating for their respective roles in splicing and the relative effects of synonymous mutations to these constructs. Some of the crucial sequences are in zones of the coding DNA called ESL's and ESS, or exon splicing enhancer/silencer (Fairbrother, 2002; Wang, 2004). Variations in any of these structures will dramatically affect the genes' ability to fold into canonical alternate splicings or novel evolutionarily beneficial/deleterious alternate splicings. Any of these mutations, synonymous or non-synonymous, could have this effect because it is a strictly splice oriented mutation. There is a phenotypic study documenting splice mutations, many of which are synonymous, which are responsible for a number of lethal diseases displayed in Table 2 (Cartegni, 2002; Chamary 2006). Clearly, disease is a survival factor; thus, exon definition implications are an easy fitness factor.

Translational kinetics could also hypothetically transduce synonymous gene mutations to phenotype through codon usage and the subsequent variations in time for protein production. These variations appear to have a significant effect on protein folding (Tsia, 2008). There are those who argue that such effects will likely not have an effect on a mammalian population due to its small size (Parmely, 2007; Sharp, 1995). The arguments presented in this paper suggest, at least a broader interpretation of this allegedly small effect. In vitro studies reveal that in translational reactions of CA, a synonymous mutation causing a translational stall results in the malformation of the protein and a 20% decrease in potency of the protein (Komar, 1999). It is fair to conclude that this was not the fault of an element external to the ribosome itself, as this was an in vitro experiment. Similarly, MDR1 experiences folding modification in response to a C3435T synonymous mutation, resulting in a striking 50% degradation of the protein due to faulty folding. This folding error can be saved by a threefold increase in trypsin, a rare amino acid. This rescue is good evidence that the mechanism of transduction of the modified phenotype from the synonymous mutation is via codon usage resulting in a translational stall (Kimch, 2007). This particular mutation has a slightly more complex relation to fitness, as the mutated gene is involved with potent and drug resistant proliferation of cancer cells. An organism with this mutation would certainly improve its lifespan.

Each of these examples only explains a static effect of a synonymous mutation. But evolution is a kinetic process which involves equilibrium and progression. The following is an investigation of a set of data presenting relative levels of synonymous mutation correlated with relative amounts of a fitness signifying mutation:

isochores.

As an alternative measure of fitness, isochores allow special insight into the meaning of synonymous mutations, as they are themselves a measure of fitness. Current observations in the study of isochores define the phenomenon as the increase in GC richness

Gene	Mutation	Loss	Mechanism	Disease
ALDH3	C59G		ESF activates spectrum cryptic	Congenital disorder of glycosylation type 1a
APC	H423R H652R H653R		155T	Familial adenomatous polyposis
AR	3088S		1413T disrupted?	Androgen-insensitivity syndrome
ATM	N766S S1135S	10/25	855S conserved	Skeletal dysplasia
ATR	G677D		3' 5S disrupted	Skeletal dysplasia
CYBB	A66A		9 mRNA structure?	Skeletal dysplasia
CYP27A1	G1120I		1455 5S disrupted	Cheroideroidosis
FAH	N232N		25 5S conserved	Hemolytic syndrome type 1
FRS3	D218I		81 4U-cons	Marfan syndrome
GLDC	P969P		22 5S17	Glycine encephalopathy
HBA2	G22G		19 5S conserved	Thrombotic thrombocytopenic disease
HEXA	L187R V324V	5/1	9 5S disrupted? 5' 5S conserved	Hexosaminidase B-deficient gangliosidosis
HMBIS	R28R		3451I disrupted?	Acute intermittent porphyria
HPRT1	F106F		81 4U-cons	Lesch-Nyhan syndrome?
ITGB3	T420T G480I	9/11	mRNA structure? 9 5S conserved	Gastric cancer
LAMB3	H106H		207 5S conserved	Junctional epidermolysis bullosa
LICAM	C366G		855S conserved	X-linked hydrocephalus
LIPA	Q279Q		81 4U-cons	Cholesteryl ester storage disease
MAPT	L286L N286N S305S		151I or 155 disrupted 155	Intermediate dementia with parkinsonism
MLH1	S575S		10 disrupted? 5 5S disrupted	Microsatellite instability
NP1	K534K		10 4U-cons	Hereditary spherocytosis
OR6A1	R594R		7 5S disrupted	Neurofibromatosis type 1
PAH	V366V		18 4U-cons	Autosomal recessive optic atrophy
PDUFA1	G180G		11 5S1I disrupted?	Phenylketonuria
PGLR	A425A		6 5S1I disrupted	X-linked Leigh syndrome
PFRF1	P60P		9 4U-cons	Phenylalanine deficiency
PTS	E38E		4 5S disrupted	Multiple sclerosis
PYGM	K666K		15 4U-cons	PTPS (glyoxylate hydratase) deficiency
RLT	R47I		11 5S17	Microtia disease
SMN1	F260F		7 5S1I disrupted	Hirschsprung disease
TGFB2	G900G		6 5S disrupted	Spinal muscular atrophy
TNFRSF25	T191I		5 5S1I disrupted	Marfan syndrome
UMOD	E34E		9 5S1I disrupted	Immunodeficiency with hyper IgM
				Familial polyposis cutanea tarda

Table 2. Mutation by gene causing exon definition mechanism disruption resulting in specific diseases.

correlated with an increase in base mutation rate for the average rate followed by a decrease in GC-richness and complimentary increase in AT-richness correlated with the populations' decrease in base mutation rate (Byre Walker, 2001; Galtier, 2001). This is the justification for GC contents' utility in hypothetical fitness correlation. Recently, isochores were investigated in parallel with synonymous and non-synonymous mutation levels. As expected, as the GC-content of a gene increased, local Dn/Ds ratios decreased. More specifically, adapting regions described by high Dn/Ds and GC-content had low levels of Ds mutations whereas the low Dn/Ds and GC-content regions had much higher levels of Ds (Berglund, 2009). These results suggest a system in which adaptation induces an increase in non-synonymous mutations, which results in increased instability of mRNA. High GC content in mRNA is a mechanism for mollifying the inevitable pre-translational degradation of new phenotypes. Once the gene has reached a favorable adaptation, the synonymous mutations begin to modify the mRNA to a stable form without changing to protein structure, so that this new phenotype may be expressed in an energetically efficient manner. Once a kinetic equilibrium is reached, GC richness is no longer needed to maintain the mRNA molecule, and the gene regresses to the original GC content of ~42-44%, at which point the synonymous mutations start again to maintain the protein structure and the mRNA fortitude. These relative levels of Ds apparently correlate to fitness of the gene and may be said to be evolutionarily relevant. It is important to realize that this Ds variation occurs with unknown dependence in this situation, so this is hardly a definite conclusion. Formally testing this hypothesis would require a situation including a controlled non-synonymous mutation rate to observe true genome level, a controlled quantity of synonymous changes to fitness, and a time point controlled evolutionary study.

DISCUSSION

Each of the channels of potential mechanistic execution of Kinetic mRNA is an explicit example of how a synonymous mutation may affect fitness. These examples implicate the plausibility of synonymous mutation relevance to fitness. Although each example is only a small illustration justified by the elements of fitness (survival, mating, and offspring), they suggest much larger potential trends which must be explored further in a whole genome exploration. These trends represent molecular methods of transduction, and therefore have the potential to affect many phenotypes and many elements of fitness. Additionally, this effect may be of any varying degree of potency: in some cases strong enough to affect selection on a behavioral level in mammals with small effective population sizes. Further evidence for evolutionary context of synonymous mutations appears in the majority of this sample with the mutations emerging as deleterious. This is important because it fits the current theories of evolution which deem the majority of new mutations deleterious (Kimura, 1977; Ohta, 1992). Though considerations of mRNA kinetics complicate fitness models, mRNA kinetics appears to be a relevant factor in deciding the fitness of an organism.

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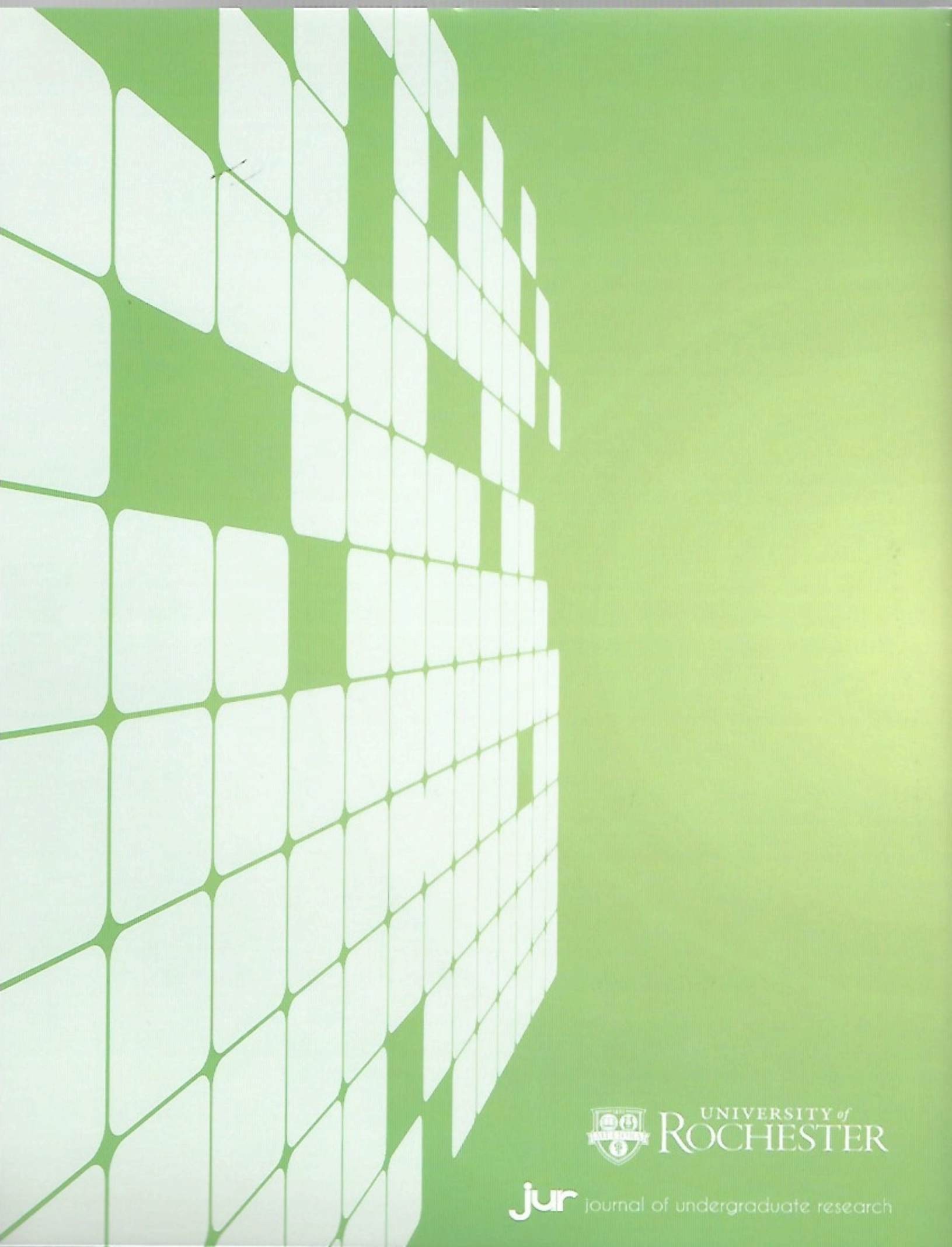
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