

# DISCUSSIONS

The Case Western Reserve University Undergraduate Research Journal

## PATIENTS' PERSPECTIVE ON COMMUNICATION:

ELDERLY CANCER  
SURVIVORS' EXPERIENCES  
WITH THEIR DOCTORS

*Jessica Saw*

POLYCAPROLACTONE-  
BASED POLYURETHANE  
COMPOSITE FOR

## FUNCTIONAL ORTHOPEDIC IMPLANTS

*G. Connor Evans*

## GASTROINTESTINAL HISTOLOGY

IN KNOCK OUT MOUSE  
MODELS AND TEMPORAL  
INDUCTION OF CFTR PROTEIN  
FUNCTION IN MICE

*Kirtishri Mishra*

— AND —

## SHARING SACRED SPACE

A HISTORY OF ROCKEFELLER PARK

*David Carter*

*Fall 2011*  
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# LETTER FROM THE EDITOR

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Dear Readers,

Welcome to a new school year and a new issue of *Discussions*! I am proud to present you with a high quality issue containing articles on a range of subjects. College students involved with research deserve recognition for their effort and skill, so we are more than happy to showcase some of their work.

If you are not familiar with the format of *Discussions*, we accept research papers from all disciplines and from any university. **The deadline for this semester's submission is October 21st.**

We are also looking for new members. You can be from any major and don't need to have experience with research. As a reviewer, *Discussions* is a low commitment group with a couple of meetings a semester. If you want to become more involved, you can become a copy editor, join the advertising committee, help design the journal, or even run for the Executive Board. We will be losing most of our executive members by the end of this year, so positions are going to be up for grabs.

For this issue, I would like to make a special shout out to our members who have graduated: Kim Girosky and Emily Moore. Kim was a dedicated reviewer/copy editor and also did a wonderful job with creating the layout for both the 2011 issues. She even took the time to help out at this year's Freshman Student Activities Fair.

Emily showed similar commitment to *Discussions*. She was a member for three years and a spectacular advertising chair for two years. Not only was she on top of her duties but went above and beyond by organizing seminars and an info session.

Last but not least, I would like to thank our previous editor-in-chief, Sean Yeldell. Sean has been a constant figure at meetings and other *Discussions* events. No matter how many questions we have, he is always available to help. Most recently, he created this issue's cover: a photo of Mahatma Gandhi from the Cleveland Cultural Gardens (a subject of the "Sharing Sacred Space" article).

Hope you enjoy the second 2011 issue of *Discussions*! **As usual, send your submissions, questions, or opinions to [discussions@case.edu](mailto:discussions@case.edu).** Further information is available on the final three pages of the journal.

Cheers,

Bharathi Muthusamy, Editor-in-Chief



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# PATIENTS' PERSPECTIVE ON COMMUNICATION: ELDERLY CANCER SURVIVORS' EXPERIENCES WITH THEIR DOCTORS

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Jessica Saw

Jessica is a fourth-year pre-med student at Oberlin College and Conservatory of Music. She is currently enrolled in the five-year double-degree program, where she plans to graduate with a Neuroscience major and Chemistry minor from the College, and a Piano Performance major from the Conservatory of Music.

Jessica is a site leader in Immerse Yourself in Service. She is also a member of the Oberlin Student Cooperative Association, where she head cooks Pizza Night at Pyle Inn Co-op. In her spare time, Jessica enjoys contra and swing dancing, cooking, baking, and playing in pit orchestras.

## ABSTRACT

This study focused on perspectives of 176 older adults who reported a cancer diagnosis. Respondents were interviewed regarding positive and problematic communication experiences with their physicians, offering an “insider perspective” on their lived experiences. Using a qualitative approach, we classified six themes reflected in patient narratives. About one-fifth of the respondents (19%) offered examples of problematic health care and communication experiences, while two-thirds (65%) provided examples of positive experiences with their physicians. This data offers evidence about the salience of the positive doctor-patient communication experiences for the elderly. Although examples of problematic communications were less frequent, they are notable in calling attention to areas for needed improvement in physician communication with their patients. In particular, many patients reported experiencing discordance with their doctors. An important finding was a differentiation of two types of discordance; the disagreement either occurred exclusively between the doctor and the patient, or it commenced between multiple doctors and was consequently translated to the patient. The themes garnered from this study suggested areas of positive and problematic communication that may become directed towards patient proactivity or physician education.

## INTRODUCTION

Cancer is a life threatening illness that poses many challenges to survivors. However, by offering patients information, social support, empathy, at-

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tentive listening, and collaborative care, physicians can provide positive communication that may serve important functions in improving patients' experiences (Arora, 2003; Epstein & Street, 2007; Ha, Anat, & Longnecker, 2010). Physicians must pay particular attention to initiating positive communication with older patients because older patients may lack assertiveness and tend to be compliant (Kahana, et al., 2009). Furthermore, elderly patients are more prone to having their cancer being treated inadequately (Fentiman, Tirelli, & Monfardini, 1990). Due to a growing number of cancer incidences with a particularly higher incidence occurring in the elderly, it is important to direct doctor-patient communication research towards the population of the aging patients diagnosed with cancer (Devesa, Blot, Stone, Miller, Tarone, & Fraumeni, 1995). Reflections by these elders about their communication experiences may offer useful insights toward improving doctor-patient communications for diverse age groups and illnesses.

The present study is unique in considering reports given by older cancer patients evaluating their health care and their communication with their doctors. In the expanding body of literature attempting to analyze the quality of doctor-patient communication, there has been relatively little patient-driven data, particularly based on elderly patients (Kahana E. & Kahana, 2007). Reviews of the literature on doctor-patient communication reveal that few studies regarding helpful communications in cancer treatment focus on patients' perspectives (Stajduhar, Thorne, McGuiness, & Kim-Sing, 2010). In fact, many studies are done from the researchers' perspective (Roter & Hall, 2006), where a third party rates the quality of communications reflected by voice or video recordings of doctor-patient communication in controlled settings.

By collecting responses directly from the patient, we were able to obtain both qualitative and quantitative information. This differs from the observational approach, where only quantitative data can be acquired (Arora, 2003). Our research appreciates the value of both the quantitative and qualitative research method regarding studies in communication. We thus used a mixed methods design that can combine benefits of considering responses to both closed- and open-ended questions. Combining quantitative information with complementary qualitative responses enhanc-

es and adds more depth to the analysis. Because "human communication is an ongoing dynamic process and not a one-way, fixed sequence of events" (Hagihara & Tarumi, 2006), it is beneficial to allow the respondent to freely elaborate on open-ended questions without constraints or limits. This allows us to capture a broader spectrum of the patients' perspectives and "understand the world as seen by the respondents" (Patton, 2002). In turn, such understanding can offer guidelines for making improvements in patient care and achieving greater patient satisfaction (Tarantino, 2004).

## METHODS

### Sample:

Interviews were conducted with 176 elderly adults who had reported cancer diagnosis from participants of a panel study of 1,107 community-dwelling elderly adults. The respondents ranged in age from 65 to 102 years, with a mean age of 80 years (SD=7.5). 65% were female and 55% were married. 95% classified themselves as white, 4% as black, and 1% as other. The most common cancer diagnosis was breast cancer at 24%, followed by prostate cancer and melanoma at 15% and 13%, respectively. The remainder of the respondents had less common forms of cancer, which included colorectal, bladder, and lung cancer. Time since cancer diagnosis ranged from less than one to 65 years, with a mean of 10.3 years (SD=11.9). 36% of the respondents had at least one previous cancer experience.

### Procedures:

In personal interviews, both closed- and open-ended questions were utilized to capture the elderly respondents' health care and communication experiences, emotions, and opinions regarding their doctors. For the closed-ended questions, the interviewers recorded whether the respondents experienced positive and/ or problematic communication, along with the extent of such communication. As for the open-ended questions, responses were coded using a standardized staged content analysis process, where raters independently read narratives and coded them into categories (Patton, 2002). Respondent narratives of positive and problematic communication with doctors were analyzed to identify themes from the open-ended questions.



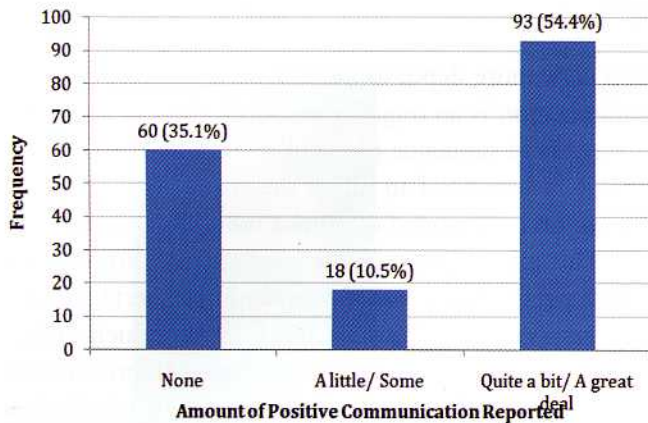


Figure 1. A U-shaped distribution describes the amount of positive communication received by respondents (N=171).

## RESULTS

Responses to closed-ended questions regarding the amount of positive and problematic communication received from physicians are shown in Figures 1 and 2, respectively. Our data indicate that 64.9% of the sample experienced positive communication, while 19.1% reported problematic communication. Conversely, 35.1% of the respondents reported no positive communication experiences, while 80.8% reported no problematic communication. The two percentages within each comparison roughly complement each other; the difference between them may be accounted by the fact that reports of positive and problematic communication are not mutually exclusive.

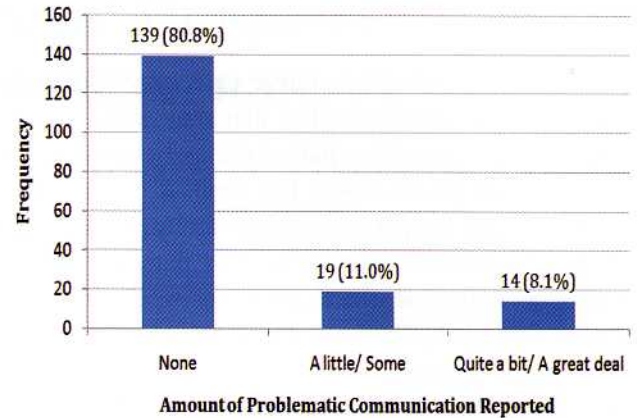


Figure 2. About one-fifth of the respondents experienced at least a little or some amount problematic communication (N=172).

A U-shaped pattern describes the distribution of the amount of positive communication reported. Most respondents (89.5%) reported either a large amount or no positive communication; few (10.5%) were in between. Over one-third (35.1%) of the respondents stated they did not receive any positive communication. As for problematic communication, a majority of the respondents reported no problems in communicating with their doctors (80.8%). The number of respondents who reported a little/ some problematic communication was roughly equal to the number of respondents who reported quite a bit/ a great deal of problematic communication (11.0% and 8.1%, respectively).

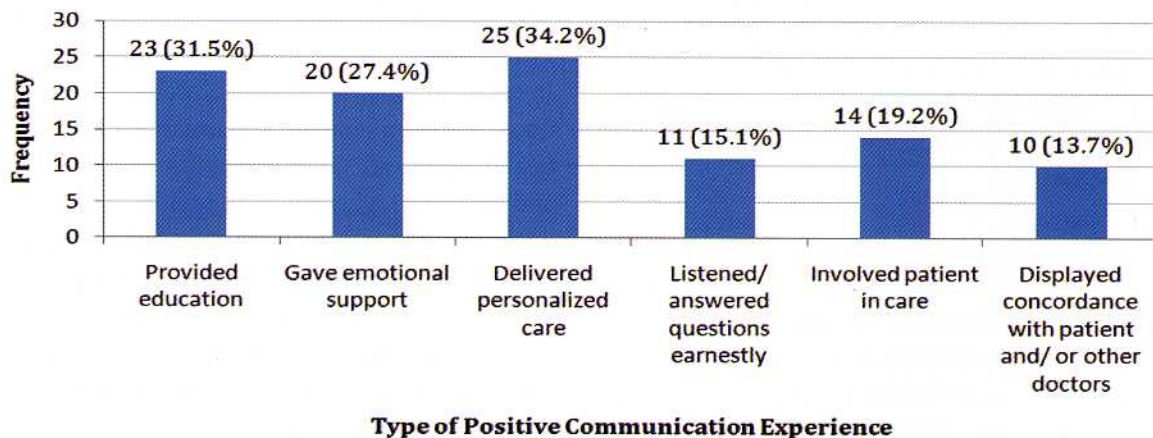


Figure 3. Six themes were drawn from respondents' examples of positive communication experiences (N=73). Some examples given by respondents may offer more than one theme, as they are not mutually exclusive.



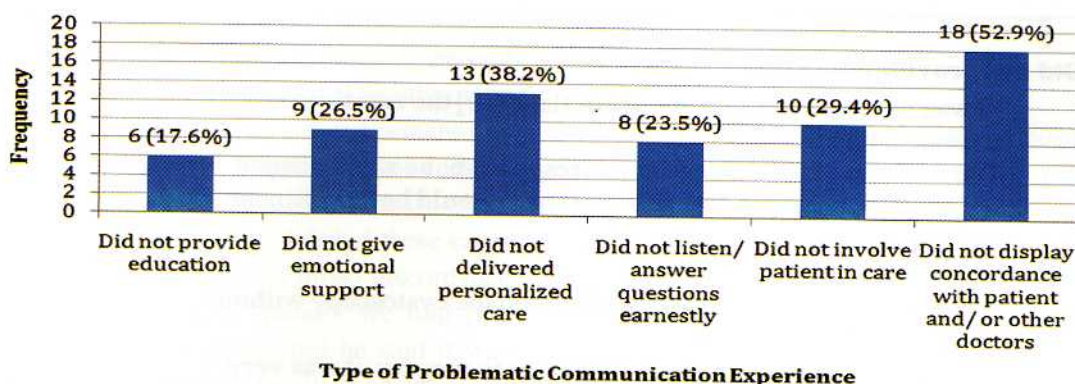


Figure 4. Themes drawn from respondents' examples of problematic communication experiences (N=34) reflected the absence of the positive communication themes. Some examples given by respondents may offer more than one theme, as they are not mutually exclusive.

Complementing the closed-ended responses, open-ended responses provided qualitative data that specified the types of communication respondents experienced. The following six themes, depicted in Figures 3 and 4, were identified in open-ended questions regarding positive experiences reported by patients: the doctor (1) provided education, (2) gave emotional support, (3) delivered personal care, (4) listened and answered questions earnestly, (5) involved the patient in care, and (6) concurred with the patient and/ or other doctors. For example, a patient who described her urologist as "very nice and kind" specifically noted how "he explained everything" and how she "trusted his opinion". This patient experienced communication that allowed her to receive education and personalized care from her doctor.

When referring to positive communication experiences, the 73 respondents commented most on how doctors delivered personalized care (34.2%), provided education (31.5%), and gave emotional support (27.4%). The following quote from a patient exemplifies a response categorized under the themes of personalized care and emotional support: "[My primary doctor] listened to me and [gave] me support. He knew I was upset because I had cancer again." Additional examples are provided in Table 1. Respondents also reported the following types of positive communication experiences: doctors listened/ answered questions

	*n (%)
<b>Provided education</b>	<b>23 (31.5%)</b>
- The urologist "gave me literature" and "provided statistical data as reference."	
- The doctor "explained my options thoroughly but left the final decision up to me."	
<b>Gave emotional support</b>	<b>20 (27.4%)</b>
- The surgeon "dropped everything to help me... and talked me through all 10 months of chemo."	
- The doctors "were supportive and kind to me."	
<b>Delivered personalized care</b>	<b>25 (34.2%)</b>
- The surgeon "visited [me] in-person when I was in the hospital" and "called everyday to give a report when I was at home."	
- The doctors "were readily available by phone and answered any and all questions, no matter how trivial or unrelated."	
<b>Listened/ Answered questions earnestly</b>	<b>11 (15.1%)</b>
- The doctors "were readily available by phone and answered any and all questions, no matter how trivial or unrelated."	
- The urologist "listened to my concerns and supported me."	
<b>Involved patient in care</b>	<b>14 (19.2%)</b>
- The doctor "explained my options thoroughly but left the final decision up to me."	
- The surgeon "gave me choices and information so I could make the best decision for [myself]."	
<b>Displayed concordance with patients and/ or other doctors</b>	<b>10 (13.7%)</b>
- "One doctor told the other doctor I could take tamoxifen and [the second doctor] agreed."	
- The urologist's "attitude was the same as mine."	

Table 1. In many of the patients' positive communication examples, doctors delivered personalized care, provided education, and gave emotional support (N=73). Some examples given by respondents may offer more than one type, as they are not mutually exclusive.



	<b>n (%)</b>
<b>Did not provide education</b>	<b>6 (17.6%)</b>
- "I was not told anything about hot flash [or] the emotional trauma I experienced"	
- The urologist "was completely unresponsive; he said I needed my prostate removed and didn't tell me I would be incontinent and impotent."	
<b>Did not provide emotional support</b>	<b>9 (26.5%)</b>
- "The urologist was cold; [he] performed the cystoscopy without anesthesia. He was a sadist!"	
- "I had to wait six weeks from diagnosis to surgery; it was very worrisome."	
<b>Did not deliver personalized care</b>	<b>13 (38.2%)</b>
- "I have bad veins and [the doctors] wouldn't listen to me when I told them how to take my blood."	
- "The oncologist seemed aloof [and] uninterested."	
<b>Did not listened/ answer questions earnestly</b>	<b>8 (23.5%)</b>
- The OB/GYN was "abrupt and quick to answer."	
- "I have bad veins and [the doctors] wouldn't listen to me when I told them how to take my blood."	
<b>Did not involve patient in care</b>	<b>10 (29.4%)</b>
- "I didn't have the opportunity to ask questions."	
- "[The doctors] wanted to do more to me than I wanted."	
<b>Displayed discordance with patients and/ or other doctors</b>	<b>18 (52.9%)</b>
- The oncologist "said it was lymphoma; I have it in writing, but I'm not convinced."	
- "One doctor said I had cancer, one said I didn't, and one did not know."	

Table 2. Over half of the respondents who gave examples of problematic communication experienced discordance with their doctors (N=34). Additionally, many of the problematic communication experienced reflected a lack of personalized care. Some examples given by respondents may offer more than one type, as they are not mutually exclusive.

earnestly, involved patient in care, and displayed concordance with patients and/ or other doctors.

Problematic experiences that were reported reflected the absence of the above-mentioned themes bit regarding doctors' behaviors. As an example of a problematic experience, one patient interacted with a doctor who "wouldn't answer questions...wouldn't tell [her] what was going on, and didn't realize it was worse [to not tell her]." In this case, the patient did not receive sufficient education. Table 2 lists further examples of problematic communication.

When referring to problematic communication experi-

ences, respondents commented most on doctors' discordance or lack of agreement regarding diagnosis or treatment. Half (52.9%) of the 34 respondents who provided such communication experiences reported doctor-patient discordance. Two types of discordance were observed; indirect and direct discordance. Indirect discordance was defined as disagreements rooted amongst doctors, which led to the patients' disbelief of the diagnosis or lack of confidence in the treatment. In the end, we observed that the patient's evaluation of health-related information differed from the doctor, which is the standard definition of discordance (Szász & Hollender, 1956). 66.7% of the discordance cases fell under the indirect category. One such



case occurred when a patient consulted three opinions, only to find that "one doctor said [he] had cancer, one said [he] didn't, and one said he didn't know." The other type of discordance, which was defined as a disagreement isolated in the relationship between only the doctor and patient, accounted for 33.3% of the discordance cases. Since there was no third party involved, we labeled these cases as "direct discordance." An example of direct discordance comes from the following patient quote: "We told [the doctor] twice the spot was changing, but he said it was okay. We insisted on biopsy and [the results showed] it was melanoma."

Another category that garnered a higher number of responses was a lack of personalized care; 38.2% of the responses mentioned this type of negative communication. An example of this theme occurred when a "doctor did not realize a side effect was coming on," since each person responds to treatments and medications in a unique way. Furthermore, 29.4% of respondents reported their doctor did not involve them in their care. For example, one respondent experienced "some problems reaching the doctor," while another felt his surgeon was "non-communicative." "My wound kept draining, so I had to go back for a second surgery to stop the drainage," he said. A further lack of patient involvement is evidenced by the fact that this patient was never told instructed to go to an oncologist.

## DISCUSSION

Overall, older cancer patients appreciate positive communications from their physicians; particularly in education, emotional support, and personalized care. These three categories are linked through their direct effect of involving the patient in care. Because education improves patient understanding of medicine (McBean & Blackburn, 1982), patients who receive appropriate education have a factual foundation towards the decision of their treatment. Those who receive emotional support and personalized care are more compelled to voice their concerns to their doctors (Maguire, Faulkner, Booth, Elliott, & Hillier, 1996). By being more open, they will be able to receive better care from their doctors, since doctors report that "openness" is a trait of helpful patients (Steinmetz & Tabenkin, 2001). These findings support the notion that the patient can be more proactive in achieving a positive experience in interacting with their doctor (Kahana E. & Kahana, 2003;

Kahana E. & Kahana, 2007; Kahana E., Kahana, Wykle, & Kulle, 2009).

In considering the preponderance of positive communications reported by older patients, we must recognize that older adults may under-report problematic communication due to the social desirability of expressing satisfaction with their care (Fabroni & Cooper, 1989; Ray, 1988). Because of the basic human tendency to present oneself in the best possible light, respondents are often unwilling to accurately report on sensitive topics (Fisher, 1993). Additionally, given the long-term survivorship of many respondents, we must also consider potential recall bias, where longer periods of recall correlate with increased inaccuracy of respondents' reports (Clarke, Fiebig, & Gerdtham, 2008). Therefore, the frequency of problematic communication occurrences may be higher than reported in this study and respondents may have described examples of problematic communication with less breadth and detail.

In addition to positive communication examples, problematic communication examples also contribute to the concept of patient proactivity. Many of the respondents who experienced problematic communication with their doctors noted a satisfactory change after they took initiative and switched doctors. For example, instead of giving an example of a problematic experience, one patient gave the following response: "Once I changed my primary care doctor, everything was fine."

This research also provides clinical implications for the doctor as well as the patient in terms of creating a more positive health care experience. These findings, particularly the positive communication themes regarding patient-desired interactions drawn from patients' responses, reflect the skills needed by doctors to diminish the impersonality of modern medical science (Dixon, Sweeney & Pereira Gray, 1999). In an era where concrete evidence like lab results and other quantitative data dictate diagnosis, many doctors may not fully appreciate the importance of using positive communication to relay the diagnosis of a disease to their patients.

In addition to analyzing positive narratives, by considering open-ended responses from patients who had problematic experiences, we can suggest steps that physicians can take towards improved communication with their patients. Giv-



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en the large proportion of respondents who reported a lack of positive communication, doctors must understand patients' perceptions of problematic communication experiences because it highlights areas in which doctors can focus more attention. For example, since over half of the problematic communication examples fell under the category of discordance, doctors should direct more attention toward enhancing concordance.

In our study, respondents reported two types of discordance; direct and indirect. Direct communication challenges the essence of the doctor-patient relationship, as the patient is directly involved in the disagreement. In this case, the patient takes on one belief, while the doctor takes on another. This straightforward type of discordance raises questions that act as a cause for conflict. In the end, we observe a relationship lag, where the two parties are unable to meet at the same level. On the other hand, in indirect communication, the patient is more removed from the conflict. The patient feels the secondhand effects of the problematic doctor-doctor relationship, where the doctors disagree with each other. These effects, which are ultimately the origin of indirect communication, are observed when doctors do not clearly communicate their differing opinions to the patient. Consequently, indirect discordance implies ambiguity and a cause for confusion. This raises questions of direction for treatment and thus, the patient-doctor relationship suffers from not a relationship lag, but an information lag.

By examining the possible causes of both types of discordance, we can provide ways to prevent this common theme in problematic communication. For example, when patients disagree with their doctors in direct discordance, the disagreement is associated with psychological stress and thus

decreases the ability of the patient to process information (Sewitch, Abrahamowicz, Dobkin, & Tamblyn, 2002). To relieve psychological stress in the elderly population, one must factor in not only the context of the stress, but the variability on how each elderly patient responds to a stress (Lazarus & DeLongis, 1983). Thus, to prevent direct discordance, physicians must use at least three of the positive communication themes obtained from this study: they must listen and answer questions earnestly to clear any confusion due to the psychological stress, they must provide emotional support to alleviate the mental and physical hardships created by cancer diagnosis and treatment, and they must deliver personalized care to account for the variation in stress coping of the elderly.

On the other hand, in the case of indirect discordance, problematic communication occurs from a lack of clarity when the doctor passes information to the patient. By providing patients with records substantiating their assessment of the patient's situation and available options (i.e. copies of test results or data from prior research), doctors are able to avoid cases of indirect discordance; this points to the value of providing patient education. Additionally, because patients are likely to have questions regarding doctors' differing opinions, doctors must be keen on listening and answering questions earnestly.

Our research provided valuable insights into the world of communication between doctors and elderly patients diagnosed with cancer. Examples of both positive and problematic communications noted by patients suggest avenues for improving communication in healthcare for both patients and doctors.

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# POLYCAPROLACTONE-BASED POLYURETHANE COMPOSITE FOR FUNCTIONAL ORTHOPEDIC IMPLANTS

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## ABSTRACT

Composite materials containing polycaprolactone based polyurethane and tricalcium phosphate were created and tested. These materials are intended for use as mechanical bone implants, requiring them to be biocompatible, biodegradable, osteoconductive, rigid, and melt processable. Commercial and synthesized polyurethane were used in tests. Commercial polyurethanes were compounded with calcium phosphate up to 50wt% in melt processing. Synthesized polyurethanes were compounded with calcium phosphate up to 50wt% in melt processing and up to 5% in synthesis. Dynamic mechanical analysis revealed storage modulus and loss modulus of all materials increased with increased calcium phosphate content. The T<sub>g</sub> of commercial polyurethane was determined to be approximately -22°C and synthesized polyurethane approximately 30°C. Tensile testing revealed the Young's modulus of all materials increased with increased calcium phosphate content. DSC revealed expected polycaprolactone thermal transitions as well as a cold crystallization transition in synthesized polyurethanes.

## INTRODUCTION

Advanced implant materials for orthopedic surgery are in use and development. The importance of medical applications allows for the selection of high value materials. These materials are chosen to improve surgical outcomes and decrease recovery time. A common orthopedic implant group is bone fixation implants. These implants are designed to attach important functional materials and tissues to bones in specific places. Examples of bone fixation implants are suture anchors and tenodesis screws. Suture anchors are used in applications such as rotator cuff repair in which a detached rotator cuff muscle is fixed to the bone while it heals. Tenodesis screws are used in applications such as ACL repair in which a tenodesis screw fixes a detached ACL in a bone cavity while the tendon heals.

Bone fixation implants may be made from permanent or biodegradable materials. Common permanent materials are titanium and polyether ether ketone. Common biodegradable materials are polyethylene glycol, polyglycolic acid, and polylactic acid. Permanent implants are designed to either remain in the body or be removed. Biodegradable implants are designed to degrade over a period of time as the body regenerates the displaced tissue. The benefit of biodegradable implants is that they transfer stresses to the healing tissue, do not require removal surgery, and are less likely to cause osteoporosis like



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rigid metal implants.<sup>1</sup> Reducing the incidence of revision surgery dramatically reduces recovery time and number of required surgeries. Osteoconductive materials such as calcium phosphate may be mixed with the degradable material to improve bone regrowth. Calcium phosphate is very similar in structure to hydroxyapatite, the primary mineral making up bone structure. Biodegradable materials also offer a platform for drug delivery research.<sup>2</sup> Hydrolytic degradation of polymers such as polyglycolic acid causes the release of an acidic byproduct.<sup>3</sup> Reducing the release of byproducts with potential to cause reactions would improve repair quality.

Polyurethanes are a common class of materials used in biodegradable implants. The versatile nature of the carbamate linkage allows for the tailoring of important material characteristics. Their elastic and foamable nature makes them popular in many implant applications including endoprostheses, cardiac valves, and regenerative membranes.<sup>4</sup> Rigid biodegradable polyurethane materials are largely unexplored. Rigid polyurethanes are found in many nonmedical applications including insulation, wood substitutes, furniture, etc.<sup>5</sup> Polyurethanes are formed from a polyol "soft-segment" and a multifunctional isocyanate "hard segment". The mechanical properties of the material may be chosen by the size and nature of these segments. Rigidity may be imparted by increasing the relative size of diisocyanate "hard-segments" or cross-linking. Additionally, chain extenders, cross-linking agents, and fillers may be added to the material. It is desirable to develop polyurethane that is biocompatible, biodegradable, melt processable, and mechanically suitable for use in a bone fixation implant.

It is proposed that polycaprolactone based polyurethane be developed as a functional implant material. The material will be made from polycaprolactonediol (Figure 1), methylene diphenyl diisocyanate (Figure 2), butanediol chain extender (Figure 3), and tricalcium phosphate filler. Polycaprolactone is known for its biocompatible and biodegradable nature as an implant material. Methylene diphenyl diisocyanate is a rigid multifunctional isocyanate that is used in existing biodegradable implant materials.<sup>6,7</sup> Toxicity exhibited in methylene diphenyl diisocyanate is considered as tradeoff for the rigid properties that it imparts.<sup>8</sup> Short polycaprolactone chains with an average Mn of approximately 530 will be used in the polyol in order to

decrease the effect of the "soft segment". The molecular weight of the material will be increased using butanediol chain extender. Increasing rigidity through cross-linking is not suitable because it is prohibitive of melt processing. Increasing rigidity through large aromatic "hard segments" is not suitable because of their lack of biocompatibility, especially in a biodegradable application. Tricalcium phosphate will be used as a filler to improve the mechanical characteristics and osteoconductive material. Filler mixing will be tested both during synthesis and melt processing. Polyurethane synthesized with no calcium phosphate is designated "0wt% synthesized polyurethane". Polyurethane synthesized with 5wt% calcium phosphate is designated "5wt% synthesized polyurethane". A commercially available polymer synthesized from polycaprolactone, methylene diphenyl diisocyanate, butanediol, and dipropylene glycol (Figure 4) will be used as a comparison and in the testing of processing and com-

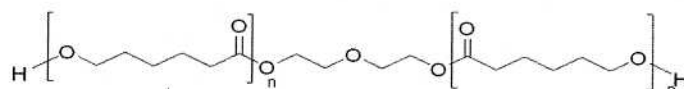


Figure 1: Polycaprolactonediol<sup>9</sup>

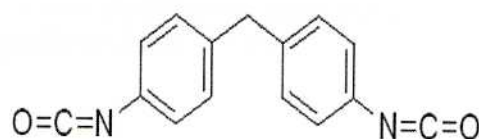


Figure 2: Methylene diphenyl diisocyanate<sup>10</sup>

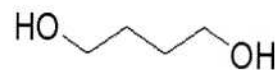


Figure 3: Butanediol<sup>11</sup>

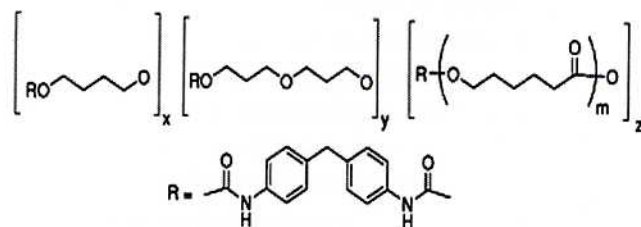


Figure 4: Chemicals contained in commercial polyurethane comparison<sup>12</sup>



Material	Compounding	Calcium Phosphate	T <sub>g</sub>	25°C Storage	37°C Storage	25°C Loss	37°C Loss
		(wt%)	(°C)	(MPa)	(MPa)	(MPa)	(MPa)
Commercial	None	0	-14.28	31.97	27.42	4.20	2.57
	Melt	0	-23.79	36.68	25.05	3.72	2.10
		5	-18.23	52.77	44.74	6.67	4.59
		10	-21.43	69.01	52.14	8.32	4.87
		20	-27.40	76.44	64.62	8.47	5.59
		30	-25.81	98.42	94.84	14.00	9.09
		40	-22.48	115.00	97.80	12.01	8.45
		50	-22.12	99.76	74.36	10.66	6.71
Synthesized	Melt	0	42.92	1391.00	199.80	163.50	180.90
		5	30.96	289.90	63.02	170.60	39.03
		50	30.76	499.60	174.00	211.30	73.83
	Synthesis	5	30.70	1078.00	55.22	404.90	83.53

Table 1: DMA results for commercial and synthesized polyurethanes

pounding. This comparison material is designated “commercial polyurethane.”

## RESULTS AND DISCUSSION

### *Dynamic Mechanical Analysis*

Dynamic mechanical analysis was performed on commercial, 0wt% synthesized, and 5wt% synthesized polyurethanes. General DMA results may be found in Table 1. Commercial and 0wt% synthesized polyurethanes were tested with calcium phosphate filler content up to 50wt% through melt compounding. All samples underwent tensile strain cycling over a temperature range from -70°C to at least 50°C. All storage modulus, loss modulus, and  $\tan \delta$  data may be found in Appendix 8.1.

The T<sub>g</sub> was determined as the peak maximum of  $\tan \delta$ . The T<sub>g</sub> of commercial polyurethane is approximately -22°C and synthesized polyurethanes is approximately 30°C. This difference in T<sub>g</sub> indicates that synthesized polyurethane may have a greater molecular weight than commercial polyurethane. The commercial polyurethane is also expected to have a lower T<sub>g</sub> due to its di(propyleneglycol) component. Di(propyleneglycol) reduces the T<sub>g</sub> of materials because it acts as a plasticizer.<sup>13</sup> All materials exhibited a T<sub>g</sub> below normal body temperature of 37°C.

No discernable change in T<sub>g</sub> of commercial polyure-

thanes was observed over the range of calcium phosphate wt%. Variability in T<sub>g</sub> between samples is attributed to differences in thermal history through melt pressing and extruding. It is notable that the T<sub>g</sub> of 0wt% synthesized polyurethane is much higher than other synthesized polyurethane measurements. This difference may be due to an anomaly in thermal history for the sample. Compounding with calcium phosphate may reduce the polymer molecular weight by degrading the polymer chains, thereby decreasing the T<sub>g</sub>.

The storage modulus and loss modulus of commercial polyurethane with up to 50wt% calcium phosphate were compared from -70°C to 50°C (Figure 5, Figure 6). The storage modulus and loss modulus are both seen to increase with increased calcium phosphate filler. The lower and upper storage moduli at -70°C the storage moduli are respectively approximately 2700MPa for 0wt% and approximately 4600MPa for 50wt%. The lower and upper peak loss moduli are respectively approximately 250MPa for 0wt% and approximately 410MPa for 50wt%. This increase in storage modulus and loss modulus indicates that calcium phosphate filler has a reinforcing effect on the material. The storage modulus and loss modulus were recorded at ambient room temperature of 25°C and normal human body temperature of 37°C (Figure 7, Figure 8). The storage modulus and loss modulus are both seen to increase with increased calcium phosphate filler at both temperatures.



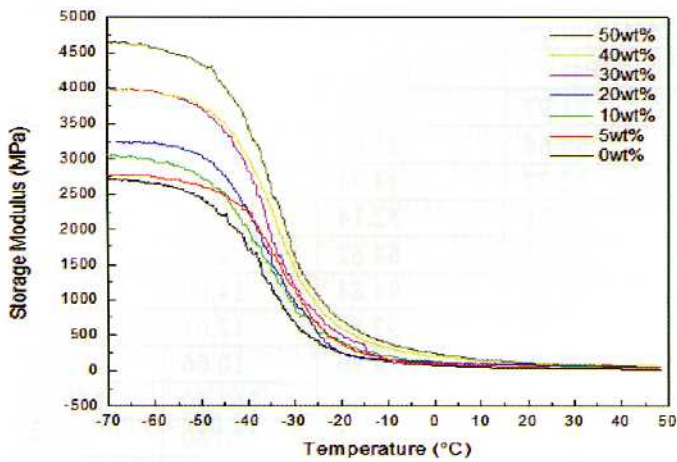


Figure 5: Storage modulus of commercial polyurethane composite with calcium phosphate

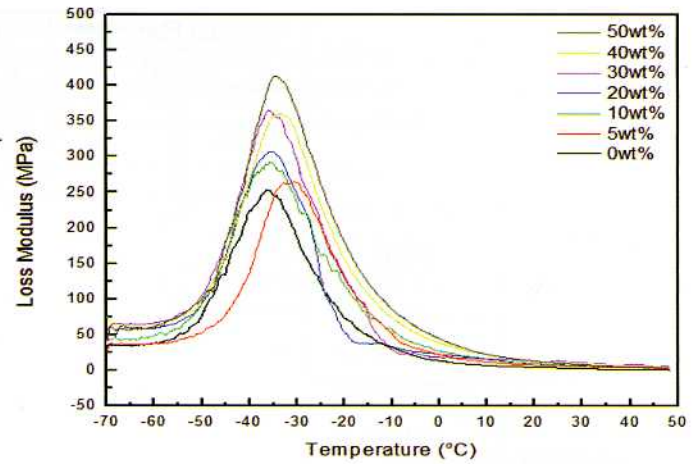


Figure 6: Loss modulus of commercial polyurethane composite with calcium phosphate

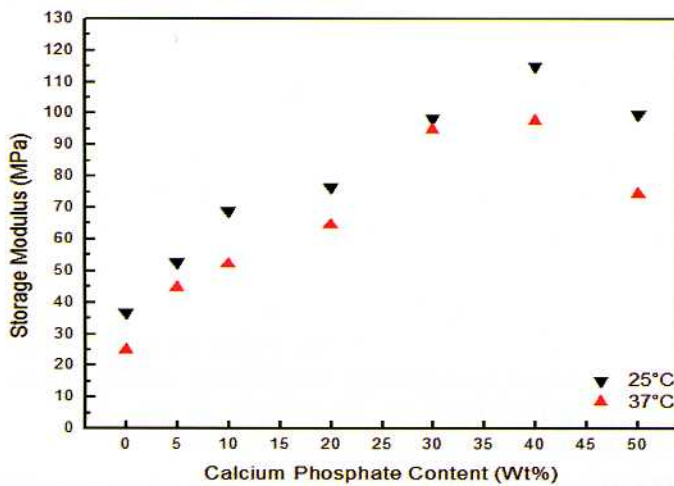


Figure 7: Storage modulus of commercial polyurethane composite with calcium phosphate at 25°C and 37°C

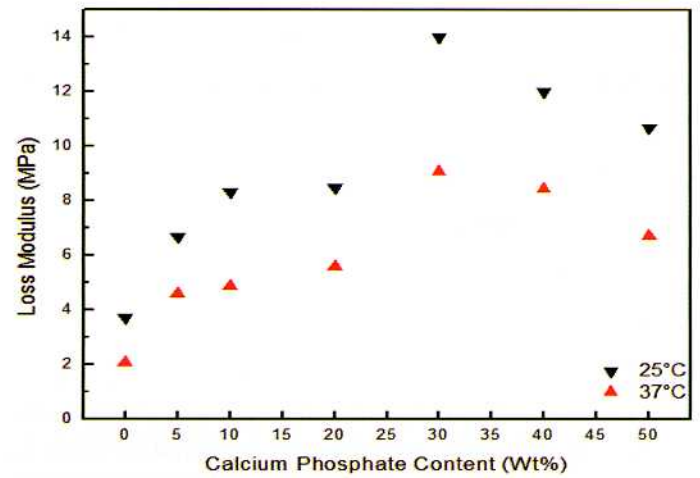


Figure 8: Loss modulus of commercial polyurethane composite with calcium phosphate at 25°C and 37°C

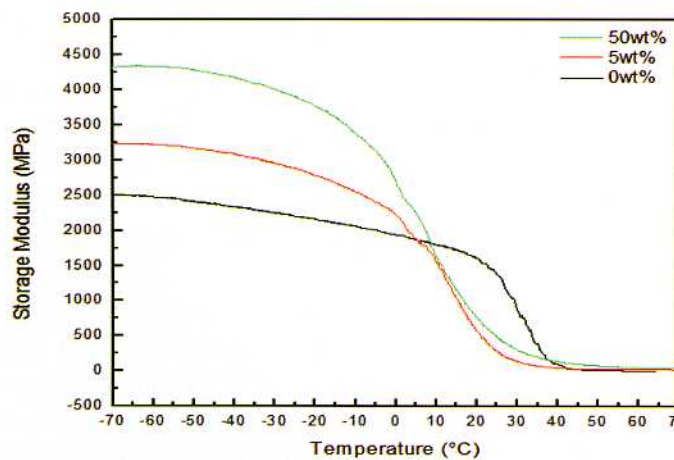


Figure 9: Storage modulus of 0wt% synthesized polyurethane composite with calcium phosphate

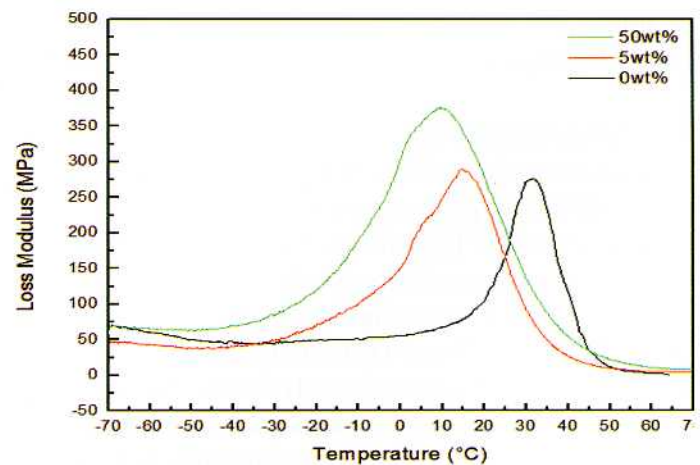


Figure 10: Loss modulus of 0wt% synthesized polyurethane composite with calcium phosphate



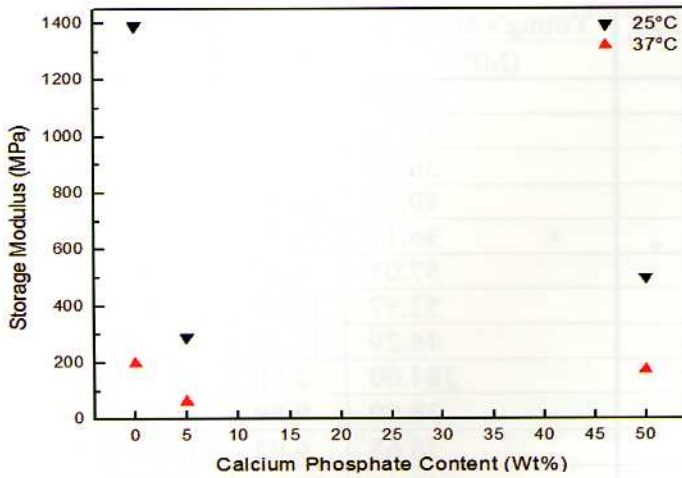


Figure 11: Storage modulus of 0wt% synthesized polyurethane composite with calcium phosphate at 25°C and 37°C

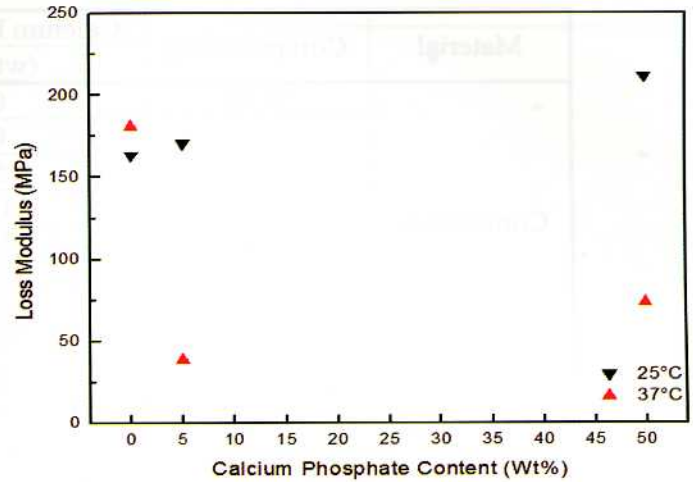


Figure 12: Loss modulus of 0wt% synthesized polyurethane composite with calcium phosphate at 25°C and 37°C

The storage modulus and loss modulus are both seen to increase with increased calcium phosphate filler. The lower and upper storage moduli at -70°C the storage moduli are respectively approximately 2500MPa for 0wt% and approximately 4400MPa for 50wt%. The lower and upper peak loss moduli are respectively approximately 280MPa for 0wt% and approximately 380MPa for 50wt%. The storage modulus and loss modulus were recorded at ambient room temperature of 25°C and normal human body temperature of 37°C (Figure 11, Figure 12). No definite trend is observed in this data due to the small number of sample measurements and the close proximity to the material Tg.

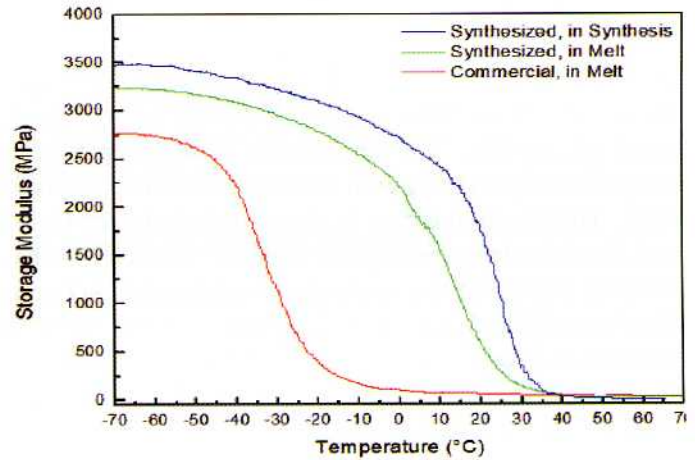


Figure 13: Storage modulus of commercial, 0wt% synthesized, and 5wt% synthesized polyurethane composites with 5wt% calcium phosphate

The storage modulus of commercial, 0wt% synthesized, and 5wt% synthesized polyurethanes were compared from -70°C to 70°C (Figure 13). Commercial and 0wt% synthesized polyurethanes were melt compounded to 5wt% calcium phosphate. Both synthesized composites have a larger storage modulus than the commercial composite at temperatures less than approximately 40°C. This difference is primarily due to the Tg of the commercial polyurethane is approximately -22°C while the Tg of the synthesized polyurethanes is approximately 30°C. The commercial composite has a larger storage modulus than either synthesized composites at temperatures greater than approximately 40°C. At this temperature all materials have exceeded their Tg rendering their amorphous phase mobile.

### Tensile Analysis

Tensile testing was performed on commercial, 0wt% synthesized, and 5wt% synthesized polyurethanes. General tensile testing results may be found in Table 2. All testing was performed at 25°C. Commercial, 0wt% synthesized polyurethanes were tested with calcium phosphate filler content up to 50wt% through melt compounding. Young's modulus and yield data were obtained for all samples. Yield stress and strain were calculated at the onset strain of the relaxation transition. Testing device strain limit was reached prior to sample failure in all measure-



Material	Compounding	Calcium Phosphate	Young's Modulus	Yield	
		(wt%)	(MPa)	(%)	(MPa)
Commercial	None	0	26.24	18.17	3.734
	Melt	0	26.49	14.74	2.841
		5	30.45	12.55	3.060
		10	40.96	12.32	4.143
		20	36.11	13.27	3.832
		30	57.03	9.45	4.125
		40	52.57	11.72	4.549
		50	48.29	11.58	4.301
Synthesized	Melt	0	384.60	2.96	9.104
		5	38.60	9.89	3.387
		50	78.65	6.02	4.335
	Synthesis	5	43.41	14.14	4.569

Table 2: Tensile testing results for commercial and synthesized polyurethane

ments unless otherwise stated. All stress-strain data may be found in Appendix 8.2.

The stress-strain relationship of commercial polyurethane with up to 50wt% calcium phosphate was compared (Figure 14). The stress-strain relationship is seen to significantly increase with increased calcium phosphate filler. There is an increase in stress-strain between 0wt% and 30wt% calcium phosphate content. There is no discernable change in the stress-strain relationship between 30wt% and 50wt% calcium phosphate content. Young's modulus and yield stress increased with increased calcium phosphate content (Figure 15, Figure 16). Yield strain decreased with increased calcium phosphate content (Figure 17). The modulus after yield of 50wt% commercial polyurethane is significantly lower than that of other commercial composites.

The stress-strain relationship of 0wt% synthesized polyurethane with up to 50wt% calcium phosphate was compared (Figure 18). Polyurethane processed without any calcium phosphate filler exhibited a visibly unique stress-strain relationship. This relationship is characterized by a larger Young's modulus of 384.6MPa and lower yield strain of 2.96% than any other samples tested. There is also evidence of necking after yielding. This unique stress-strain relationship is due to the material being well below its T<sub>g</sub>. The T<sub>g</sub> of this sample was 42.92°C as reported in DMA, which is significantly greater than that of any other sample. The stress-strain of 50wt% calcium phosphate content is seen to be greater than that of 5wt% calcium phosphate content. Young's modulus, yield

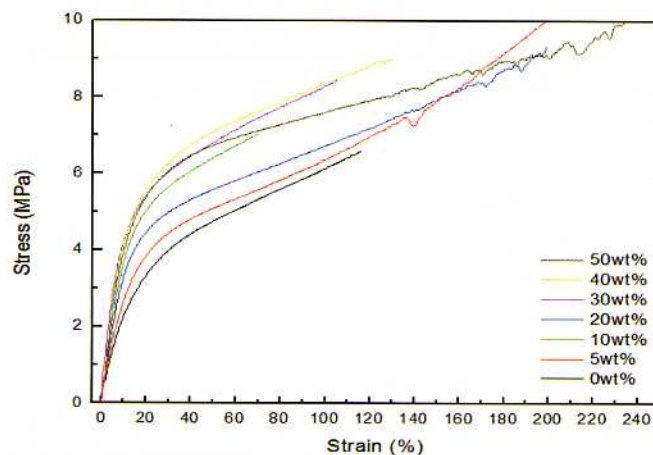


Figure 14: Stress-strain relationship of commercial polyurethane composite with calcium phosphate

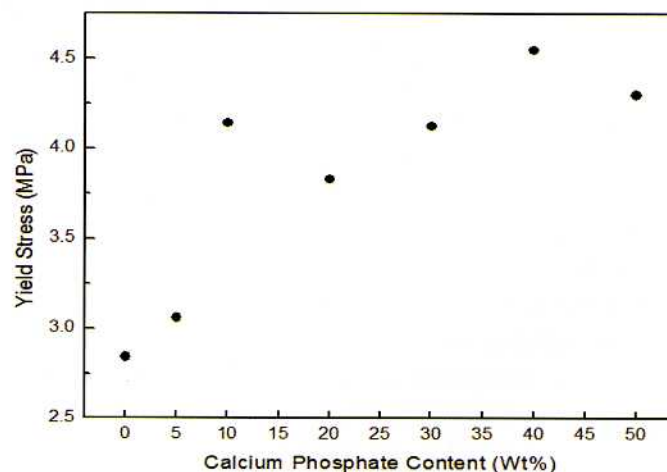


Figure 15: Yield stress of commercial polyurethane composite with calcium phosphate



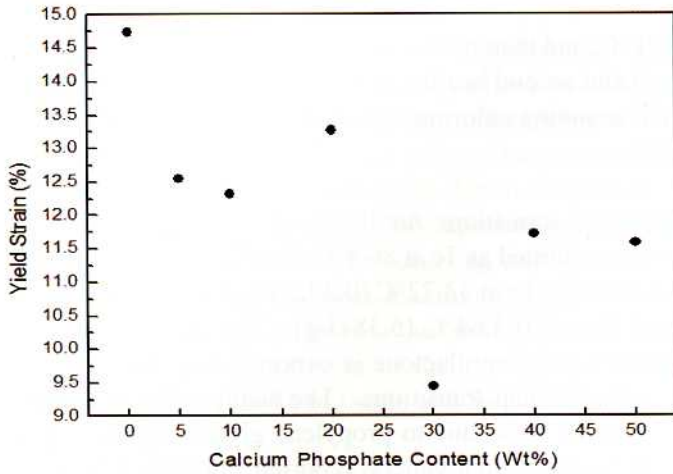


Figure 16: Yield strain of commercial polyurethane composite with calcium phosphate

stress, and yield strain data are not adequate to determine trends (Figure 19, Figure 20, Figure 21). More intermediate samples are necessary to determine a definite trend in stress-strain due to calcium composite content. It is notable that the 50wt% compounded polyurethane was the only sample to fail prior to completion of testing. This failure indicates that greater calcium phosphate filler content makes the material more brittle.

The stress-strain relationship of commercial, 0wt% synthesized, and 5wt% synthesized polyurethane was compared (Figure 22). Commercial and 0wt% synthesized polyurethanes were melt compounded to 5wt% calcium

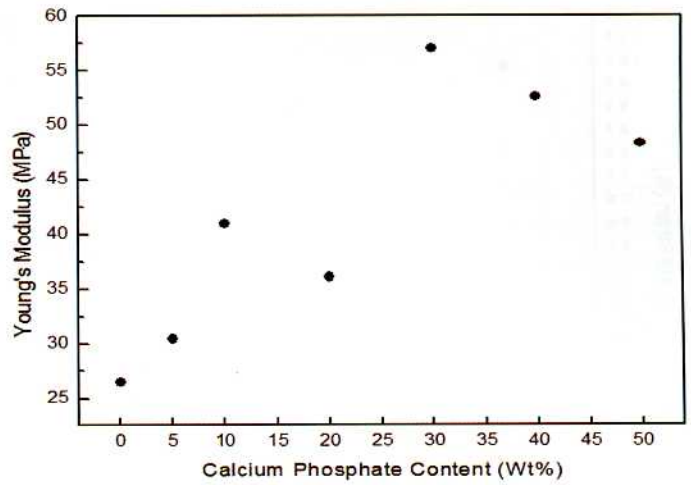


Figure 17: Young's modulus of commercial polyurethane composite with calcium phosphate

phosphate. Both synthesized composites have a greater stress-strain than the commercial polyurethane composite. This difference is partly due to the Tg of the commercial polyurethane being approximately -22°C and the Tg of the synthesized polyurethanes being approximately 30°C as reported in DMA.

#### Differential Scanning Calorimetry

Differential Scanning Calorimetry was performed on commercial, 0wt% synthesized, and 5wt% synthesized polyurethanes. All samples were heated to 250°C, cooled to

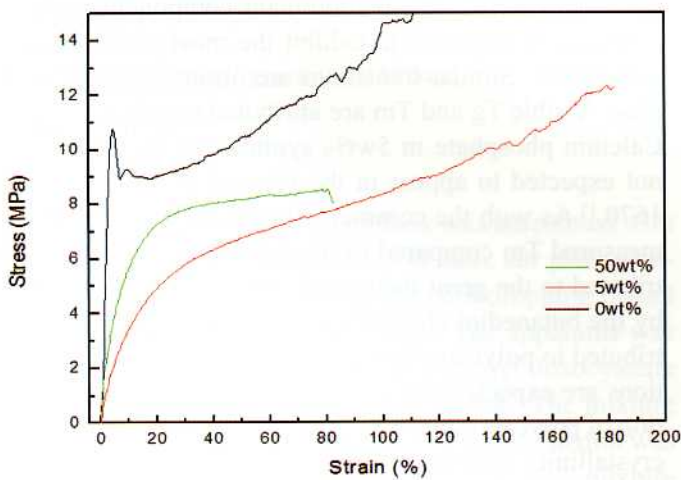


Figure 18: Stress-strain relationship of 0wt% synthesized polyurethane composite with calcium phosphate

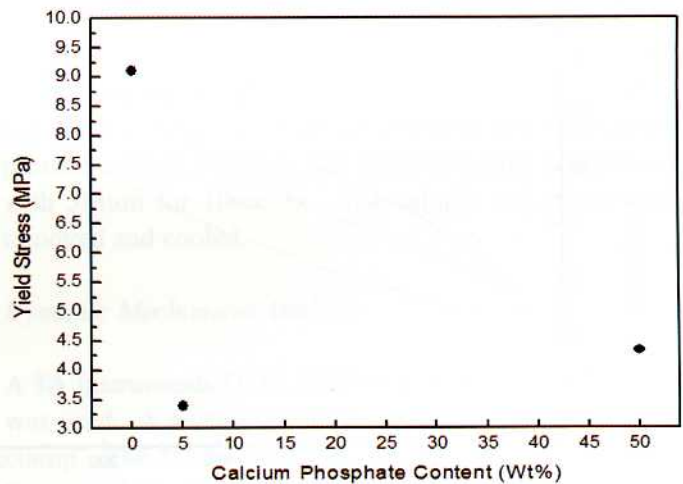


Figure 19: Yield stress of 0wt% synthesized polyurethane composite with calcium phosphate



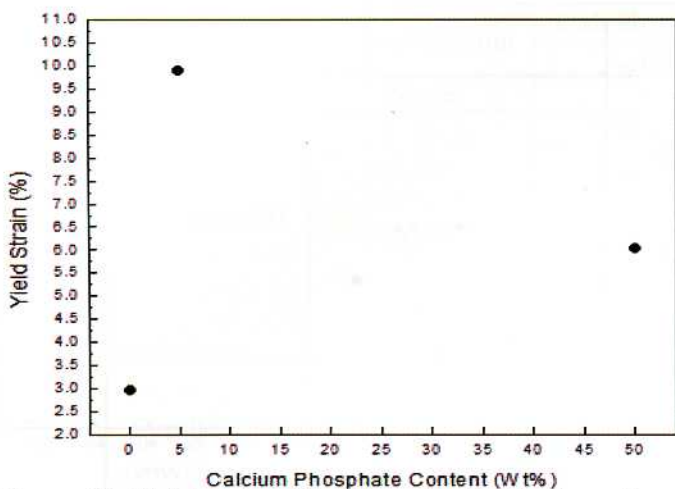


Figure 20: Yield strain of 0wt% synthesized polyurethane composite with calcium phosphate

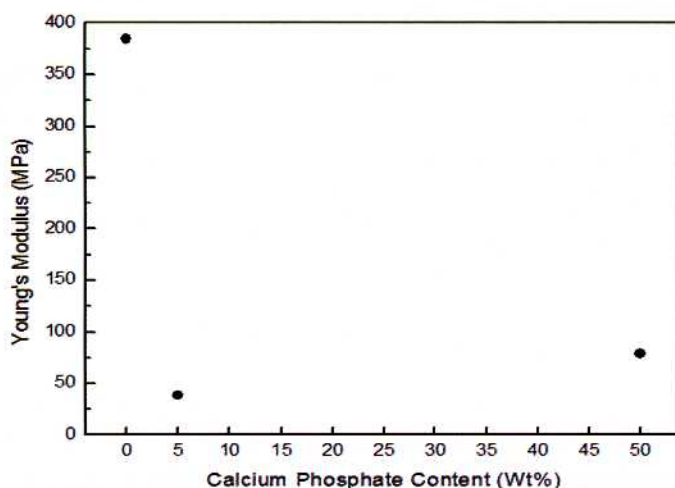


Figure 21: Young's modulus of 0wt% synthesized polyurethane composite with calcium phosphate

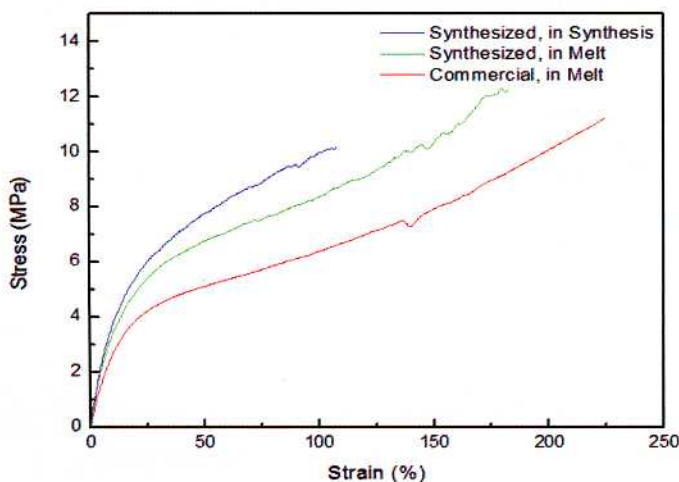


Figure 22: Stress-strain relationship of commercial, 0wt% synthesized, and 5wt% synthesized polyurethane composites with 5wt% calcium phosphate

-70°C, and then heated to 250°C. Data from the first cooling and second heating cycles was analyzed. All differential scanning calorimetry data may be found in Appendix 8.3.

Thermal transitions for 0wt% synthesized polyurethane were exhibited as  $T_c$  at 86.4°C (9.692J/g),  $T_m$  at -25.61°C (4.582J/g),  $T_g$  at 33.72°C (0.2725J/(g•°C)) during heating, and  $T_m$  at 163.64°C (5.381J/g). The predominant component, polycaprolactone is expected to exhibit the most visible thermal transitions. The shallow  $T_m$  at -25.61 is suspected to be due to propylene glycol segments. This  $T_m$  is similar to a general reported  $T_m$  of polypropylene glycol of -49.9°C.<sup>14</sup> The  $T_g$  and  $T_m$  at 163.64°C are attributed to polycaprolactone segments. The  $T_m$  is significantly greater than a general reported polycaprolactone  $T_m$  of 59-64°C.<sup>15</sup> This increase in  $T_m$  is expected due to the great increase in molecular weight created by the butanediol chain extender. The measured polycaprolactone crystallinity for the  $T_c$  is 7% and for at 163.64°C  $T_m$  is 4%. The heat of fusion for polycaprolactone used was 139.5J/g.<sup>16</sup>

Thermal transitions for 0wt% synthesized polyurethane were exhibited as  $T_c$  at 52.02°C,  $T_g$  at 13.83°C (-0.2516J/(g•°C)) during cooling,  $T_g$  at 19.38°C (0.4629J/(g•°C)) during heating,  $T_{cc}$  at 64.26°C (5.969J/g), and  $T_m$  at 140.03°C (10.16J/g). Thermal transitions for 5wt% synthesized polyurethane were exhibited as  $T_c$  at 21.19°C,  $T_g$  at 5.04°C (-0.1277J/(g•°C)) during cooling,  $T_g$  at 18.47°C (0.1980J/(g•°C)) during heating,  $T_{cc}$  at 70.21°C (1.468J/g), and  $T_m$  at 131.13°C (2.371J/g). In both synthesized materials the predominant component, polycaprolactone is expected to exhibit the most visible thermal transitions. Similar transitions are observed in both samples. Visible  $T_g$  and  $T_m$  are attributed to polycaprolactone. Calcium phosphate in 5wt% synthesized polyurethane is not expected to appear in the thermal cycle as its  $T_m$  is 1670.<sup>17</sup> As with the commercial polyurethane, the greater measured  $T_m$  compared to the general reported  $T_m$  is attributed to the great increase in molecular weight created by the butanediol chain extender. The  $T_c$  and  $T_{cc}$  are attributed to polycaprolactone. These crystallization transitions are expected due to the favorable crystalline formation of polycaprolactone. The measured polycaprolactone crystallinity in 0wt% synthesis for  $T_{cc}$  is 4% and for at  $T_m$  is 7%. The measured polycaprolactone crystallinity in 5wt% synthesis for  $T_{cc}$  is 1% and for at  $T_m$  is 2%. The heat of fusion for polycaprolactone used was 139.5J/g.<sup>16</sup> This degree of crystallinity is low as polycaprolactone has



been reported as being as much as 59.1% crystalline.<sup>18</sup> The low percent crystallinity is due to the interaction of other polymer components with the polycaprolactone segments. The lower T<sub>g</sub> of 5wt% synthesized polyurethane compared to 0wt% synthesized polyurethane is due to the presence of calcium phosphate hindering polycaprolactone crystallization. For both tests, the T<sub>c</sub> occurring during cooling is approximated as a broad peak maximum. Percent T<sub>c</sub> is not determined as its proximity to the cooling T<sub>g</sub> prohibits isolation. This limitation reduces the significance in the noted temperatures for T<sub>c</sub> of 0wt% and 5wt% synthesized polyurethanes.

## MATERIALS AND METHODS

### *Materials*

Poly[4,4'-methylenebis(phenylisocyanate)-alt-1,4-butanediol/di(propyleneglycol)/polycaprolactone]  
(Aldrich430218-250G, Batch#02609BC)

Polycaprolactonediol  
(Aldrich189405-250G, Batch#04216DH)

4,4'-Methylenebis(phenylisocyanate), 98%  
(Aldrich256439-500G, Batch#MKBC3781)

Butanediol, ReagentPlus®, ≥99%  
(Aldrich240559-100G, 13323ED)

Calcium phosphate  
(Aldrich21218-1KG, Lot#0001447745)

### *Synthesis*

A 250ml 3-necked round bottom flask was assembled with a mechanical stirring mechanism, oil bath, stir plate, temperature controller, reflux condenser, and dropping funnel connected to an argon gas manifold. The apparatus was flushed with argon gas. Methylene diphenyl diisocyanate was added. Calcium phosphate was added. The mixture was stirred and heated to 60°C. Polycaprolactonediol was added slowly through the dropping funnel. The mixture was heated to 80°C and stirred for 4hr. Butandiol in was dimethyl sulfoxide added. The mixture was heated to 80°C and stirred for 2hr. The reaction mixture was poured

in water and allowed to sit overnight.

### *Film Preparation*

A Carver laboratory press Model C was used. The press was heated to 190°C. Polyurethane was placed between two sheets of Teflon and two steel plates. The sample and plates were inserted into the melt press which was then closed with minimal pressure. Upon returning to 190°C the press remained closed with minimal pressure for 1min then was compressed with 0.5-1Mton for 3min. The sample and plates were removed and cooled.

### *Composite Film Compounding*

A Carver laboratory press Model C was used. The press was heated to 190°C. Polyurethane film and calcium phosphate were placed between two sheets of Teflon and two steel plates. The sample and plates were inserted into the melt press which was then closed with minimal pressure. Upon returning to 190°C the press remained closed with minimal pressure for 1min then was compressed with 0.5-1Mton for 3min. The sample and plates were removed and cooled. The pressing procedure was performed 3x.

### *Measured Film Preparation*

A Carver laboratory press Model C was used. The press was heated to 190°C. Polyurethane and composite films were placed between two sheets of Teflon coated aluminum foil and two steel plates. The sample and plates were inserted into the melt press which was then closed with minimal pressure. Upon returning to 190°C the press remained closed with minimal pressure for 1min, compressed with 0.5-1Mton for 10sec 3x, and compressed with 5Mton for 10sec 3x. The sample and plates were removed and cooled.

### *Dynamic Mechanical Analysis*

A TA Instruments DMA Q800 with tension clamp fixture was used. A rectangular film sample was inserted in the clamp. The Module was set to DMA Multi-Frequency - Strain and the ProcName was set to Temperature Ramp. The initial temperature was set to -70°C. The motor drive was turned on and the sample temperature was ramped



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3°C/min to 70°C. The storage and loss modulus were measured over the temperature range.

#### *Tensile Testing*

A TA Instruments DMA Q800 with tension clamp fixture was used. A rectangular film sample was inserted in the clamp. The Module was set to DMA Strain Rate and the ProcName was set to Mark Stres-Strain. The temperature was equilibrated at 25°C. The motor drive was turned on and the sample strain was ramped 20%/min to 300%. The stress-strain relationship was measured of the strain range.

#### *Differential Scanning Calorimetry*

A TA Instruments DSC Q2000 was used. Sample was sealed in an aluminum pan. The Module was set to DSC Standard Cell RC and the ProcName was set to LC Modulated.

The initial temperature was set to -70°C. The temperature was ramped 10°C/min to 250°C. The temperature was ramped 10°C/min to -90°C. The temperature was ramped 10°C/min to 250°C. Heat flow was measured throughout the thermal cycle.

## CONCLUSIONS

Polycaprolactone based polyurethane composites for use in functional orthopedic implants was proposed. Increased calcium phosphate filler content is shown to have a reinforcing effect on the material in dynamic mechanical analysis and tensile testing. Cold crystallization was observed in synthesized polyurethanes. This crystallization may be used to optimize material characteristics through semi-crystalline fractions. Synthesized polyurethanes were observed to have a higher T<sub>g</sub> than commercial polyurethane. Increasing the T<sub>g</sub> of the materials is of interest for rigid operation in the functional environment of 37°C.

Future work will focus on improving the mechanical and biodegradable material properties through composite, thermal, and chemical processes. Increasing the calcium phosphate content in commercial polyurethane composites may reveal a maximum loading composition. Trends in 0wt% synthesized polyurethane composites may be determined through sample measurements at more calcium phosphate compositions. Synthesized polyurethanes with increased

calcium phosphate content in synthesis may determine improved material characteristics due to decreased thermal requirements compared to melt compounding. Tensile testing at 37°C is necessary to reveal mechanical properties of the materials in their intended functional environment. Tensile tests in which the sample is strained to failure in all cases are optimum. Infrared spectroscopy performed on commercial and synthesized polyurethanes may be used to determine information pertaining to difference in chemical structure. Dependence on thermal history of the materials should be analyzed and the melt processing procedures optimized for best material properties. The effect of hydrolytic degradation on the materials should be analyzed with simulated body fluid. The effect of degradation caused by atmospheric humidity should be analyzed. The cold crystallization of synthesized polyurethanes may be used to improve their material characteristics through increased crystalline content.

*Go to [case.edu/source/discussions](http://case.edu/source/discussions) for appendix.*



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# SHARING SACRED SPACE: A HISTORY OF ROCKEFELLER PARK

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Cleveland's government and interest groups have erected monuments and christened memorials in order to shape the way that citizens remember certain persons, events, groups, and eras. However, the meanings of these public monuments may transform after their construction. Just a mile northwest of the campus of Case Western Reserve University, Lower East Boulevard was constructed in the late 1890s in East Cleveland. The engineers and civil servants assigned to this construction job could not have foreseen the symbolic importance the road and the eventual surrounding parklands would come to embody. In the century since its construction, the boulevard has become prized real estate for different Cleveland groups to commemorate their respective causes and memorials. Many veteran groups, cultural and ethnic groups, and civil rights groups have memorialized their own symbols along this road, now known as Dr. Martin Luther King, Jr. Boulevard in Rockefeller Park. Different groups of Cleveland residents cooperated in and competed for the same tracts of land to memorialize what each of these groups deems sacred. I seek to analyze these groups' efforts in themselves, and paths they took to cooperation or conflict in the historical landscape of Rockefeller Park. Analyzing the perceptions of these groups in the eyes of Cleveland citizens is important as well, since it is for Cleveland's historical memory that interest groups sought to memorialize their causes. I hope to answer if and how a variety of groups can share the same physical space for their causes. Perhaps there are common threads that run through all the commemorative efforts that are now located in a three mile stretch of road through Rockefeller Park.

The story of Dr. Martin Luther King Blvd. begins in the late 1890s. John D. and Laura Spelman Rockefeller deeded to the city of Cleveland a three mile strip of land running alongside the Doan Brook, and it was named Rock-

## -Acknowledgments-

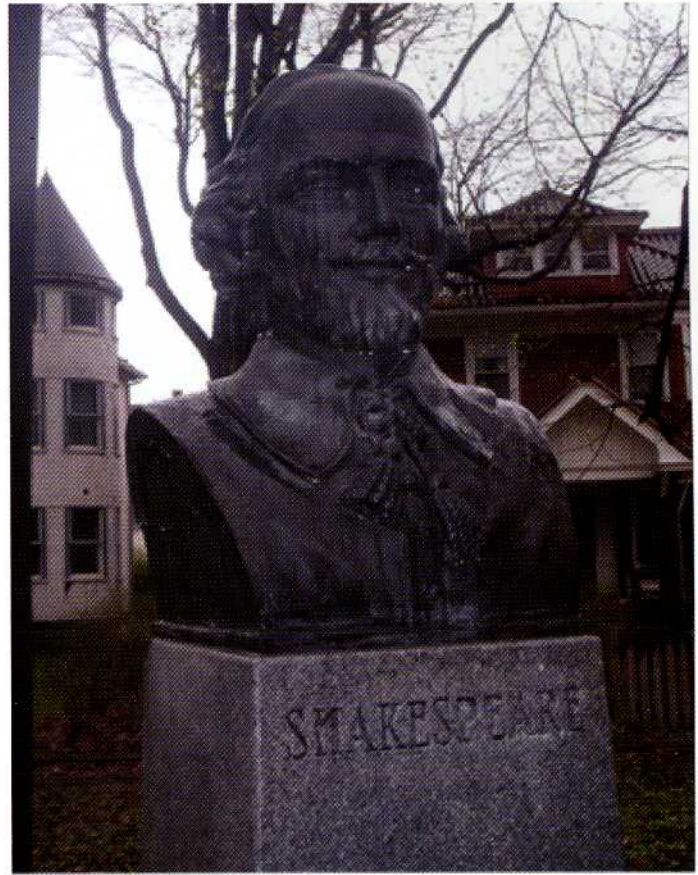
First and foremost, I would like to thank my thesis advisor Professor John Grabowski for guiding me to relevant and useful resources in the beginning stages of my research, and for offering acute yet caring criticism of my paper as I developed my thesis. Also, I would like to thank Professor Sentilles as the instructor of Case Western's History Senior Research Seminar for overseeing myself and a dozen other history majors on our arduous quest to fulfill our independent study requirement. Finally, many thanks to Martin Hauserman, the Chief City Archivist of the Cleveland City Council, and to the staff of the Western Reserve Historical Society for providing veracious direction as I dove into the Cleveland City Council Archives and the collections of the Western Reserve Historical Society.



efeller Park (“Rockefeller Park,” Encyclopedia of Cleveland History [ECH], 1998). Afterwards, world events set the stage for Cleveland groups to mobilize in order to commemorate three distinct events in American history: America’s involvement in 20th century armed conflicts, the immigrant communities of Cleveland, and the American civil rights movement. Thus, Rockefeller Park became a commemorative site for Liberty Row, the cultural gardens, and civil rights memorials.

Goldberg and Roy (2007) observe that the Greater Cleveland area is the first metropolitan area to dedicate a living memorial – a nine-mile strip of 850 white oak trees – to its fallen soldiers serving in the First World War. Furthermore, Robbins (2003) finds that planting trees as a living memorial to a nation’s deceased soldiers gained in popularity during the early 20th century, following Cleveland’s lead. Cleveland City Council passed Ordinance 47590 in 1919 to change “North Park Boulevard, running through Ambler Park, Rockefeller Park, and Shaker Heights Park from Cedar to Center Road to ‘Liberty Row,’” also known as Liberty Boulevard. A bronze tablet bearing a name of a deceased soldier of the Greater Cleveland area accompanied each sapling oak tree. To the present day, most of the bronze tablets resting at the foot of the oak trees remain intact, although some of the tablets along Martin Luther King Jr. Boulevard have been stolen or vandalized by local Clevelanders, or destroyed by vehicles leaving the confines of the road due to automobile accidents. The issue of stolen and vandalized bronze tablets will make an appearance later in this paper, but for the moment it is a safe assessment to say that the oak trees and bronze tablets still serve their purpose of commemorating fallen Cleveland soldiers of World War I.

At nearly the same time, the first “cultural garden” was dedicated in Rockefeller Park in 1916 with William Shakespeare as its main subject. Although the Shakespeare Garden meant to commemorate culture in the sense of “high culture” and not “ethnic culture,” it also served as an American symbol of solidarity with the Britain and the Entente Powers of World War I. However, this idea of a cultural garden later inspired Leo Weidenthal’s idea to prepare similar cultural gardens related to ethnic groups inhabiting Cleveland. Since then, there are now close to thirty cultural gardens in Rockefeller Park that commemorate ethnic groups, foreign nations, the United States, and groups of people such as African Americans. President George Parras of the Cleveland Cultural Gar-



**William Shakespeare, dedicated in 1916.**

dens Federation (2007) believes that “the idea of linking peace to a mutual understanding across cultures was so powerful that it was recognized internationally.” The cultural gardens drew state ambassadors and heads of state, as well as the founder of the then League of Nations and soon to be founder of the United Nations. Furthermore, former Cleveland mayor Anthony J. Celebrezze said, “I hope and trust that the basic concept behind the Cultural Gardens of Cleveland will provide the necessary impetus in the movement for better understanding among all people, and among all nations throughout the world.” Therefore, two memorialization efforts – World War I veterans and Cleveland’s cultural groups – came to fruition on the same tract of public space. Along with this, an arena for debate emerged among proponents of leaving the area as a monument to Cleveland’s World War I veterans that fell in combat and those who wanted to establish more cultural gardens in Rockefeller Park.

Finally, civil-rights campaigns swept through the United States in the period following World War II. Dr. Martin Luther King, Jr. visited Cleveland in 1956, 1961, 1963,



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1964, 1965, 1967, and 1968, and was highly active in Cleveland promoting black voter registration, fundraising efforts, and bolstering the local nonviolent civil-rights movement (“Martin Luther King, Jr., Visits to Cleveland, ECH, 1997). He was an important figure in the Greater Cleveland civil-rights campaign, and in 1981, Cleveland christened a street after him in a similar manner that cities across the nation embraced him. However, Cleveland elected Liberty Boulevard to be renamed Martin Luther King, Jr. Boulevard. Three different memorialization efforts now permeated the landscape of Rockefeller Park.

Before further investigation, it is important to examine what exactly constitutes “public memory.” The phrase “public memory” – and specifically a public memory of the Cleveland variety – presupposes that there is a singular, all-encompassing polity within Cleveland comprised of hundreds of thousands of individuals, and that the consensus public memory of this polity is the summation of the opinions of these hundreds of thousands of Clevelanders. On the contrary, Bodnar (1992) argues that public memory is not a memory formed on consensus, but rather it is the “intersection of official and vernacular cultural expressions.” The more intersections—or similarities—that different groups with power and influence in a community realize, then the greater agreement there is among what people or events should be commemorated within that community, likely leading to less conflict over what should be memorialized in that society’s sacred space. Therefore, public memory is not a greatest common factor or aggregate of the beliefs of all individuals that comprise a polity; rather, public memory is the least common denominator of what everyone agrees should be included in that public memory. Political and non-political actors can influence the development of this public memory through the resources they possess, amplifying and reducing varying aspects of the public memory to their liking or to achieve their objectives.

Turning quickly to Hungary provides an example of when there is no intersection of beliefs among different groups of people concerning what should be memorialized in public memory. As different groups came to possess power in Hungary throughout the 20th century, each group wanted to shape Hungarian public memory differently. For example, Heroes Square, built in Budapest in 1900, commemorates what Hungarians believe to be the 1000th anniversary of Hungary’s establishment. Levinson (1998) writes that the monument included “Franz Joseph himself,

sharing spaces with angels and other national heroes all incorporated into a satisfying story of national identity and historical progress.” Within twenty years of the construction of Heroes Square, however, proletarians took control of Hungary and smashed many of the monuments of Heroes Square, destroying the established public memory of conservatism and historical reverence, which opposed the progressive objectives of Hungary’s proletarian uprising. These proletarian radicals were “quickly replaced by counterrevolutionaries” and Heroes Square was restored to its original grandeur. Different groups in Hungary found no similarities (intersections) in what they believed should constitute public memory during Hungary’s tumultuous early 20th century history. Thus, the creation of a public memory in Hungary is an example of a conflict over what elites believe their society should revere. Public memory in Hungary was not an aggregate of what all Hungarians believed should be commemorated, but rather that which the leaders in society found suitable to their objectives.

The previous example displays the falsity of the claim that public commemoration creates public memory on which all members of that public agree. Rather, the possessors of power craft their public’s historical memory through the use of the society’s sacred space. Levinson continues on to argue that the act of commemoration is “rooted in the political exigencies of the moment.” Furthermore, “not the mere existence of diversity” but “disparate sources of political power” are the vehicles through which actors can communicate their views. The resulting debate shapes the public memory created for a society, and the intersections found through the dialogue of these political actors establish public memory. Thus, it does not matter what different groups in a pluralist society think should comprise that society’s public memory; political elites and groups with political power are the actors that decide where they agree concerning public memory. This is evident in Cleveland’s history; blacks did not achieve any commemorative gains in Rockefeller Park until the African American Cultural Garden was established in 1977 and the road itself was renamed Martin Luther King Jr. Boulevard, both long after the establishment of Rockefeller Park and the Cultural Gardens. Why did it take such an extended period for African Americans to establish themselves in the Cultural Gardens and in Rockefeller Park? Levinson speaks to this situation when he writes, “the changes involve... the entry of new groups into the ambit of those with genuine political clout, with the consequent necessity of responding to the demands of these groups.”



Liberty Row, the cultural gardens, and Martin Luther King Blvd. all came into existence together in the same public space because they are symbols whose intersection of cultural expressions are agreeable to the possessors of political power in Cleveland. My thesis has two parts. First, these leaders and influentials aim to promote peace and understanding in a city that has seen its share of racial and ethnic discord. However, the perceptions and reactions of non-elite Clevelanders call into the question the extent to which harmony exists among the demographic groups of Cleveland. To what extent have Cleveland's political elites used Cleveland's sacred space – in particular, Rockefeller Park – to accomplish their objective of harmony among the people of Cleveland?

### The Establishment of Rockefeller Park

Parallel to the Second Industrial Revolution and urbanization in America during the 19th century, an increasing awareness of the importance of preserving parks and establishing park systems arose among city politicians and urban planners. Responding to this trend, in 1871 the State of Ohio enacted legislation to allow for “the improvement and control of all parks in cities of the first class having a population of more than one hundred and fifty thousand inhabitants, shall be vested in a board of park commissioners.” Cleveland caught onto the park-establishing trend a little later than the rest of the nation's metropolitan areas. In the Park Commissioners' Report to the Cleveland City Council (1891), the city's Park Commissioners found that “the city of Cleveland stands to-day at the foot of the list of cities in the United States having a population of 200,000 and upwards in the matter of parks.” Cities such as “New York, Boston, Brooklyn, Philadelphia, Chicago, Baltimore, Detroit, and Buffalo” have experienced “very material benefits” from “the establishment of a well-devised park system.” Public parks “have passed beyond the domain of luxuries and may be justly classified not only as useful, but as profitable adjuncts to a populous, prosperous and thriving city.”

The report determines that “the wild and romantic valley through which Doan Brook takes its sinuous way from Doan Street to the Lake, a distance of 3 miles, is a natural park as nature has formed and adorned it; a comparatively small expenditure would render it one of the very finest parks in the country.” The Park Commissioners moved to acquire immediately this land that would eventually become Rockefeller Park and the home of Liberty Row,



Doan Brook winds its way through Rockefeller Park.

the Cultural Gardens, and Martin Luther King Jr., Blvd. “It is believed that this property can now be secured at a reasonable cost, and that its improvement would so very materially increase the value of contiguous property as to bring back to the city a handsome profit on the expenditure. This valley is so park-like in its natural state that the construction of a driveway and foot-path throughout its length would constitute the only immediate improvement necessary; further betterments and embellishments can be made covering a long series of years. Its improvement might well be made a matter of time; but its purchase should be affected at once” (Park Commissioners Report to the City of Cleveland, Office of the Park Commissioners, 1891).

Five years later in 1896, Cleveland's City Council accepted the generous donation of the above described parkland from John D. Rockefeller, who “tendered to the City of Cleveland for the benefit of all people, tracts of land and money for park and boulevard purposes, which could not be duplicated for a million dollars.” The park was dedicated as “Rockefeller Park, so that his name may go down the ages in the hearts of the present and unborn generations as one of the great names in American history who knew how to plant money where it will be immortal in culture and character” (Park Commission Record, 1893-1896). Neither Cleveland's Park Commission nor the City Council of Cleveland knew the degree to which their predictions would come true concerning the eventual importance of Rockefeller Park.



## The Dedication of Liberty Row

In a 1919 Plain Dealer article entitled “An Altar of Sacrifice,” it was reported that “Memorial Day this year takes an added significance from the nature of America’s recent activities in war and peace. Cleveland is to dedicate its Liberty Row and Altar of Sacrifice—emblems of the community’s appreciation of the magnificent service performed by her own sons.” The scenic boulevard became the home of two parallel lines of oak trees—a line of oaks on each side of Lower East Boulevard that weaves through Rockefeller Park. A bronze plate bearing the name of a fallen World War I soldier and his date of death accompanied each oak tree. The Plain Dealer goes on to write, “This is a people’s demonstration of loyal approval for what Cleveland’s soldiers, sailors, and marines did upon the battle fields of Europe.” Furthermore, a 1918 Plain Dealer article entitled “Victory Oaks” describing the victory achieved in death of the American soldiers that each tree represents; these trees would be a symbol to “Clevelanders of coming generations who shall contemplate the long rows of venerable and majestic oaks.”

Who the Plain Dealer journalists meant by “the people” and a stereotypical “Cleveland of the coming generation” are murky at best, but there must have been a feeling that there was wide agreement in the sanctity and legitimacy of this act of commemoration. However, even before “coming generations” had a chance to contemplate the memory of fallen soldiers and majesty of the oak-lined boulevard, vandals, youth, and speeding automo-



A row of Victory Oaks along North Park Boulevard



John A. Jacobson, World War I veteran killed in action.

biles were desecrating the commemoration of the fallen World War I soldiers. For instance, a 1936 Plain Dealer article “Vandals Take War Hero Markers in Liberty Row” reports that “six bronze discs, each bearing the name of a soldier who died in France, have been chiseled out of their concrete bases—at a profit to the vandals of nearly half a dollar each.” By 1930, 14 of the 830 bronze plaques were missing from their respective victory oaks (Liberty Row List). In addition to vandals, a 1922 Plain Dealer article entitled “The Soldiers’ Trees” blames adolescent automobile drivers—colloquially known as “petters”—taking their romantic interests to the dark nooks of Liberty Row and “backing their machines to the shadows” and crushing sapling victory oak trees. Although the journalist concedes that they may not “see the little oaks,” he also writes that “probably they would not care if they did see them.” Finally, the same writer also cites speeding automobilists as treacherous to the survival of the frail, young oak trees. In all of these scenarios, the writer says it is necessary to call attention to “the sacredness of the oaks” and to the recklessness of those “speeding through sacred precincts.” A comparable act would be speeding through a cemetery on Memorial Day when American flags and flowers have been brought to the graves of deceased veterans; it was disrespectful and simply was not to be condoned. Thus, in the few years since Liberty Row was dedicated, it had already captivated some Clevelanders as sacred, as well as fallen to the realm of indifference in the minds of other Clevelanders.

Even though certain groups of Cleveland society felt un-





A vandalized memorial rests in front of a Victory Oak.

bound to the sanctity that enveloped Liberty Row, there were thousands of Clevelanders who celebrated memories that Liberty Row inspired. For example, in 1921 the Plain Dealer reports that nearly 50,000 Clevelanders were on hand to witness the 10,000 veterans and participants in a Memorial Day Parade along Liberty Boulevard in the presence of the memorials of oak trees and emblazoned bronze plates. Also, “Helen” wrote in distress to the Plain Dealer’s “Miss Joy” column (1920) to ask “why are so many of the name plates missing?” Furthermore, Plain Dealer writer Henry Bailey (1920) wrote that flowers planted in the vicinity of the oaks and bronze plates added both to the beauty of Rockefeller Park and affixed another “living” component alongside the oak trees to commemorate the fallen soldiers: “From every point of view—patriotic, symbolic, aesthetic—the planting of those flowers of living green and lustrous gold is exactly right.” Finally, Cleveland’s dedication of Liberty Row inspired other cities in the United States to pursue similar methods of commemoration. Plain Dealer articles excitedly announced that Tiffin, Ohio planted trees “in Front Park as a memorial to soldiers who died in World War I” (1922), Mayor Couzens of Detroit “favors the erection in Detroit of an “altar of sacrifice” similar to the one under way here [in Cleveland]” (1922), and Fremont, Ohio had Buckeye trees engraved with the names of their hometown fallen soldiers planted on both sides of the Memorial Parkway (1920).

### Beginnings of the Cultural Gardens

A few years following the dedication of Liberty Row as a living memorial for deceased veterans of World War I, another commemoration effort was afoot in Rockefeller Park: “The Cleveland Cultural Garden Federations was founded in 1925 as the Civic Progress League by Leo Weidenthal, who, during the dedication of the Shakespeare Garden in Rockefeller Park in 1916, felt that similar sites should be prepared for each of the city’s nationality communities” (“Cleveland Cultural Garden Federation, ECH, 1998). With the dedication of the Shakespeare Garden in 1916, there was no conception or precedent for a collage of parklands running along a parkway that celebrated the diverse ethnic makeup of a metropolitan area. However, in a short decade, the idea of a cultural garden coalesced in the mind of Leo Weidenthal, and the Hebrew Cultural Garden came to fruition in 1926.

A 1929 Plain Dealer article “Gardens to Focus on Old World in City” gives an account of The German Cultural Garden recently dedicated, and “steps to establish a chain of cultural gardens throughout Cleveland” started to gain momentum among Cleveland’s nationality communities. At this early date, however, what a cultural garden would mean to various Cleveland citizens already showed signs of divergence. In the same article, Jennie Zwick, who was instrumental in coordinating the dedication of the Hebrew Cultural Garden, recognized that there are differences between ethnic groups which created a distinctive personality in each, creating a distinctive culture in which the souls of their people were represented. However, she hoped “that the entire chain of gardens will represent the search for truth that knows no race or creed.” A celebration honoring Leo Weidenthal and Charles J. Wolfram, both past presidents of the Civic Progress League, celebrated their efforts in establishing the cultural gardens “because they are acting as an inspiration for the national groups and are working to create a better understanding among the groups” (Two Honored for Cultural Gardens, Plain Dealer [PD], 1932).

Wolfram, who initiated the German Garden movement, recognized the unprecedented nature of cultural gardens and the grandeur it would bring to the city of Cleveland; the plan was “something new, never having been attempted before anywhere in the world. If the plan is developed up to expectations, the whole world will be looking at Cleveland” (“Gardens,” PD, 1932). On the other hand, the Civic Progress League representative Joseph B. Smolka of the Slovak group believed that a Slovak cultural garden “would be an outward expression of an inward feeling. If



we had a garden, we could take children there, could point out to them things which have been great in Slovak history through the centuries." Although the benefits of the outward-looking, visionary ideal of Zwick and Wolfram and the inward-looking, community-oriented goals of Smolka are not mutually exclusive, the emerging cultural garden movement already possessed different meanings to different persons. Even though the cultural gardens' meaning may not have been universally agreed upon, Cleveland's ethnic communities celebrated the cultural gardens widely after the Civic Progress League instituted them. A spring festival and costume ball of the Civic Progress League had "twelve nations officially represented at the affair, and more than 3,100 persons attended" ("Nations Link Arms in Frolic at Public Hall," PD, 1930).

#### Jewish-American veterans, the German Cultural Garden, and Liberty Row

Early in the lifetimes of both Liberty Row and the Cleveland Cultural Gardens, there were interactions and intersections in Rockefeller Park's sacred space concerning the oak trees and bronze plates commemorating fallen Jewish soldiers. A month prior to Memorial Day 1928, The Jewish War Veterans' "application for admittance" to the Joint Veterans Commission had "been held up because it was thought that to let this group in would result in opening the doors to numerous other groups, thus making the commission unwieldy and less able, therefore, to take care of veterans' needs" ("Jewish Veterans," PD, 1928). Although this effort failed, Jewish representatives were also appointed to approach "the county commissioners in the matter of obtaining grave markers for Jewish service men, and to see the director of parks about obtaining the Star of David for use on Liberty Row for those trees planted in honor of the Jewish fallen." Once Memorial Day arrived, the Jewish War Veterans were permitted to mark the trees on Liberty row with the Star of David ("Jewish War Veterans," PD, 1928). This is one of the earliest signs of cooperation among a Cleveland cultural community and the curators of Liberty Row.

America's involvement in the First World War created a common ground through which ethnic communities could integrate themselves into the Cleveland community and gain acceptance; these ethnic communities' members emigrating from areas affected by warfare strengthened their commitment to Americanize and assimilate. The City Council of Cleveland and Cleveland's various war advi-

sory committees reinforce these immigrants' efforts to assimilate into Cleveland society. For example, in 1918 the Cleveland Americanization Committee hosted "a public meeting in the council chamber of the city hall on Tuesday evening, May 7th, at 8 o'clock, to announce the winners in the prize essay contest, 'Why My Parents Came to America' recently conducted by the Cleveland Americanization Committee. The mayor will distribute the prizes, and there will be music by two national groups."

In order for a Cleveland ethnic group to perpetuate and sustain its cultural heritage inside its own community, its members needed to construct its ethnic identity in this era of intense Americanization efforts during and following World War I. Ethnic immigrants cannot be expected to cleave to patriotic memories of America's founding fathers or other patriotic memories from the colonial era, Revolutionary War, or Civil War. However, American society in general and Cleveland society in particular appreciated similar displays of patriotism to their homelands. Bodnar uses "homeland symbolism" to refer to an ethnic community's efforts to simultaneously please non-immigrant Americans' respect for ethnic patriotism through the commemoration for their ethnicity's historical leaders and symbols. Therefore, ethnic communities placing homeland symbols in their respective cultural gardens pleased both Cleveland political elites that value patriotism and the members of the Cleveland ethnic community.

This concept of homeland symbolism is what allowed the German community of Cleveland to assert their presence in the city's cultural sphere so shortly after World War I even though Germany was a wartime enemy. German Clevelanders achieved the first truly ethnic cultural garden in Rockefeller Park—aside from the Shakespeare Garden—in 1926. This achievement is incredible considering the anti-German/Prussian sentiment that remained in Cleveland after the First World War. An example of anti-German sentiment is a City Council of Cleveland ordinance passed in 1918, lambasting the German aggressors: "Whereas, the President of the United States at the beginning of the hostilities between the United States and Germany, solemnly declared that one of the aims of the United States will be the liberation of all Slavic races from the *tyranny* of the Hapsburg dynasty and explicitly named Bohemians and Slovaks as the nations first to be considered among Slavic nationalities of Austro-Hungary to be independent free states" (File No. 46288, Minutes of the Cleveland City Council [MCCC], 1918). Another



example of anti-German sentiment in Cleveland during the First World War is the efforts of the City Council petitioning Cleveland's "Commissioner of Engineering and Construction to proceed at once to furnish the Council the names of all avenues, courts, roads, and lanes in the city of Cleveland having distinctive German names" (File No.



Goethe and Schiller embody Bodnar's concept of homeland symbolism for Cleveland German-Americans.

46668, MCCC, 1918). Later records of the Cleveland City Council show the renaming of "Berlin Road that runs from Syracuse Avenue to St. Clair Avenue changed to E 182nd St" (File No. 47100, MCCC, 1918). A final example of anti-German sentiment that the German Clevelanders overcame was the drama of two City Councilmen, John G. Willert and Noah C. Mandelkorn, being expelled for expressing "German tendencies" and not being considered loyal to the United States during wartime. Their expulsion resulted in a written letter from W. J. Zoul, Adjutant of the Army and Navy Union of Cleveland which lauded City Council for expelling Willert and Mandelkorn, and thus "carrying on and winning this war against

Prussianism and for world democracy" (File No. 46794, MCCC, 1918).

In spite of the widespread anti-German sentiment at the end of World War I displayed by the city government and Cleveland groups outside of the city government, German Clevelanders achieved the first ethnic cultural garden alongside Liberty Boulevard. The juxtaposition of Cleveland's memorial to World War I veterans with a memorial to German culture could only be achieved through the use of homeland symbolism. The central figure in the German cultural garden are two bronze statues of Johann Wolfgang Goethe and Friedrich von Schiller, German heroes that possess both cultural and patriotic meaning for Germans. Surely, the Cleveland City Council would not have approved of bronze statues of Wilhelm II or Erich Ludendorff in the German cultural garden. On the other hand, both Goethe and Schiller possess two defining qualities of homeland symbols without carrying any egregious connotations; they commemorate German culture, and they embody German immigrants' patriotism. In fact, their patriotic, nationalist backgrounds comply with President Woodrow Wilson's Fourteen Points with respect to national self-determination. In this way, German Clevelanders overcame Clevelanders' anti-German sentiments by creating an intersection in public memory where their cultural community could reassert themselves into the Cleveland cultural sphere.

#### One World Day and the Hough Riots: Racial-Ethnic Tensions

Racial riots tore through Cleveland's Hough neighborhood in July 1966. A month later, a Plain Dealer journalist framed "One World Day" as an attempt to heal the riot-scars that were still fresh in the minds of Clevelanders ("One World Day's Brotherhood Theme to Replace Riot-Scars," PD, 1966). That year, One World Day saw its 21st annual celebration in the Cleveland Cultural Gardens. One World Day "accentuates the purpose for the creation and existence of the Cultural Gardens: Brotherhood, equality, democracy, and an understanding between peoples." Cleveland Mayor Ralph S. Locher further elaborated the importance of the cultural gardens in healing wounds from Cleveland's race riots and building bridges between peoples; One World Day "serves to remind us of our obligation to preserve and strengthen Cleveland as a living symbol of how people of many nationality backgrounds can join in a common effort of achievement without losing



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their individuality" ("World Day Proclaimed," PD, 1966).

In a Report on the Ethnic Task Force to the Commission on Catholic Community Action, Joe Bauer (1970) attempted to connect the experiences of ethnic Americans to black Americans. He argues that the Civil Rights Movement has encouraged the black community's search for their identity; similarly, the act of "making it" in American society has encouraged the ethnic American "to cut himself off from his roots too fast. The emergence of ethnic consciousness is a reaction to the Blacks' search for identity." Similarly, Bishop Cosgrove gave an address to the Annual Dinner of the Catholic Interracial Council of Cleveland, scolding white suburbanites for pitting "the Black and the Ethnics against each other to avoid facing their own suburban responsibilities." Suburbanites (presumably white) parasitically used the facilities, industries, and benefits provided by the multiracial, ethnic city of Cleveland while ignoring the multiple problems of the city itself.

#### Zones of Conflict: The Elite – Non-Elite Disconnect

Although rhetoric of community and peace pervades the speech of elites from veterans groups, ethnic communities, and civil rights groups, the day-to-day reality is often disconnected from the peaceful and unified Greater Cleveland society that these elites imagine. For example, Mayor Ralph Perk received a letter from a Hungarian Cleveland citizen (1969) citing the terror that he or she—the letter was unsigned due to fear of repercussions—felt in his/ her neighborhood near Buckeye Road. As Cleveland proper became a more racially integrated area, ethnic Clevelanders resented African Americans destroying the homogenous ethnic identity of their communities. On the other hand, Nicholas A. Bucur (1970), chairman of the Cleveland Industrial Trade Commission, wrote a letter to United States Vice President Spiro Agnew to suggest to him that Agnew could be the leader in a movement "to build bridges between the black community and the ethnic. The nationality movement is fragmented and needs a solid voice." Although Bucur's intentions are certainly well-meaning, the reality on the ground in Cleveland may not be as simple as he makes it appear.

The Cleveland mayoral campaign of 1969 illustrates the disconnect between Bucur's ideal that he writes to Vice President Agnew and the reality that non-elites experienced in Cleveland at the same time. Republican mayoral candidate Ralph Perk's support came from Cleveland's

multiple ethnic communities; incumbent mayor Democrat Carl Stokes' garnered much of his support from the African American community, as he was elected the first black mayor of a major United States city in 1967; and independent Ralph Locher lost the Democratic primary but chose to run for office as well. The week prior to the mayoral election, polls showed Perk a clear favorite as he rallied ethnic Clevelanders votes. However, a whispering campaign was initiated in the final week prior to the elections with the common theme that a vote for Perk would be a vote against Locher—the preferred candidate of Cleveland's non-immigrant white population—and thus a vote for electing Stokes. Votes that would have otherwise been cast for previously ethnic-supported Perk went to Locher, resulting in Stokes barely securing Cleveland's mayoral election of 1969 ("Papers of Mayor Ralph Perk," Container 1, Folder 6, Manuscript #4456). This account of Cleveland's mayoral election of 1969 illustrates the fear that ethnic Clevelanders had of reelecting the African American Carl Stokes as mayor of Cleveland. While political and cultural elites in Cleveland attempted to build bridges between the ethnic and African American communities of Cleveland, the reality of interracial fear was shown in 1969.

#### CONCLUSION

Memorials, dedications, and commemorations are created by societal elites that want to shape a public memory to fit to their objectives and goals. This is evident among the sacred spaces that inhabit Dr. Martin Luther King, Jr. Blvd. In 1977, an African American cultural garden was dedicated to the cultural gardens along Liberty Row, and in 1981, Liberty Boulevard was officially rededicated as Dr. Martin Luther King, Jr. Blvd. Except for the Shakespeare Garden, previous cultural gardens were dedicated to a particular ethnic group or nationality. Now, the African American cultural garden represents the identity of the African American community that arises from the trials and struggles that Cleveland's African-American community has endured. As all of this has occurred in Rockefeller Park, the mighty Victory Oaks have presided over the boulevard and all of these occurrences for ninety-two years.

My research and analysis points to a disconnect between the efforts and actions of influential elites in Cleveland society and the common persons and publics that elites represent. Elites attempt to construct common themes of peace, justice, and community through situating multiple



memorials in the same physical space in Rockefeller Park, creating a narrative that builds bridges between Cleveland's fractured demographics. This is certainly an admirable goal for the Greater Cleveland area, yet the rhetoric that Cleveland elites employ does not always coincide with the reality that Cleveland non-elites experience daily. Whether or not the end goals of increasing understanding, tolerance, and peace among Cleveland's peoples is achieved, Liberty Row, the Cultural Garden, and Dr. Martin Luther King Jr., Boulevard create a magnificent three mile long journey for anyone who chooses to take the time to appreciate intersections in public memory that can be found in Rockefeller Park.



The Finnish Cultural Garden and Victory Oaks reside together along Dr. Martin Luther King, Jr. Blvd.

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# GASTROINTESTINAL HISTOLOGY IN KNOCK OUT MOUSE MODELS AND TEMPORAL INDUCTION OF CFTR PROTEIN FUNCTION IN MICE

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## ABSTRACT

Cystic Fibrosis (CF) is a fatal hereditary disease that is characterized by gastrointestinal, pancreatic, and pulmonary disorders. CF is caused by a mutation in the Cystic Fibrosis Transmembrane Conductance Regulator (CFTR) gene. An inherited condition, CF causes wide defects in epithelial tissue function in an organism. This ubiquitous affect poses a challenge for researchers studying the disorder, because it is difficult to distinguish primary and secondary effects from the result from CFTR mutation. Knock-out (KO) mouse models have provided a way for researchers to delete CFTR functions from specific tissues. In order to fully understand this disease, we created a mouse model that allows us to activate/deactivate CFTR function in cells at any given time point using a drug called tamoxifen (TM). We also created a panel of mouse models showing variable levels of CFTR function. We used these mice to study the correlation of CFTR function with growth and survival seen in mice. We also used these same animals to determine if there is any correlation between the number of mucus producing cells (goblet cells) in the intestines and CFTR activity. It was established that CFTR function is necessary in the intestines for survival but it does not affect growth. Furthermore, in general animals with CFTR function reduction or deletion lead to higher number of goblet cells.

## BACKGROUND

Cystic fibrosis (CF) is a hereditary disease affecting the exocrine (mucus) glands of the lungs, liver, pancreas, and intestines, causing progressive disability due to multisystem failure. The presence of CF is directly related to the absence of the Cystic Fibrosis Transmembrane Conductance Regulator (CFTR) protein, which is responsible for the transport of chloride ions, and water molecules across epithelial layers throughout the body (1). The presence of CFTR proteins allows individuals to maintain a thick, slippery substance called mucus that lubricates and protects the linings of the airways, digestive system, reproductive system, and other organs and tissues throughout the body. However, patients with CF, who lack functional CFTR proteins, form mucus that becomes thick and obstructs the organs that they would normally lubricate. This accumulation of thick mucus in organs, such as the lungs, can provide an area of bacterial growth, which can lead to



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chronic lung infections. Over time, mucus buildup and infections result in permanent lung damage, including the formation of scar tissue (fibrosis) and cysts in the lungs.

Most people with cystic fibrosis also have digestive problems because thick, sticky mucus interferes with the function of the pancreas. The pancreas, a gland in the digestive and endocrine system, produces insulin, a hormone that helps control blood sugar levels. The exocrine pancreas makes enzymes that help digest food. In people with cystic fibrosis, mucus blocks the ducts of the pancreas preventing these enzymes from reaching the intestines to aid digestion. Problems with digestion can lead to diarrhea, malnutrition, poor growth, and weight loss. Some babies with cystic fibrosis have meconium ileus, a blockage of the intestine that occurs around the time of birth (1).

The development of transgenic mice bearing null mutations of different genes encoding channel proteins has opened a large field of investigation, which allows a better understanding of the physiological mechanisms controlled by various proteins. This novel method allows researchers to induce mutations in proteins in desired tissues and conduct a genome wide study of the affects.

CF studies have made a prolific use of the system applying the transgenic mouse scheme to study the effect of CFTR deletion in specific tissues. Dr. Craig Hodges (Department of Pediatrics, Case Western Reserve University), in coordination with Dr. Mitchell Drumm's Lab (Case Western Reserve University), has developed mice that show varying severity of CFTR deletion in the intestines. The purpose with this mouse model is to determine the correlation of CFTR activity in the organism with the survival and growth of the mice populace being studied. We will also study the correlation between CFTR activity in the intestines and the number of goblet cells present in the epithelia of the intestines. Furthermore, Dr. Hodges has created an inducible mouse system in which the CFTR gene can be activated or inactivated by tamoxifen-induced recombination. The strategy is to activate the CFTR gene in CF mice of different ages and assess the critical times of this activation on the various disease phenotypes. Before the phenotypic changes in response to CFTR activation can be assessed, it is necessary to know how well the activation system works (2).

## INTRODUCTION

In order to fully understand the tamoxifen-induced system, it is integral to introduce the mechanism behind the knock out (KO) mice that we have used for our study (Figure 1). Dr. Hodges has created these two conditional CFTR mouse models using the Cre/Lox system. The Cre/Lox system is a scheme by which small segments of DNA between two LoxP sites (34 base pairs of a specific DNA sequence) can be recombined in the presence of an enzyme called Cre-recombinase (3). Dr. Hodges created two versions of the CFTR gene with LoxP sites in it. In one case, the presence of Cre catalyzes the excision of CFTR Exon 10, inactivating the gene (Figure 1A). In the other case, the LoxP sites were inserted in such a way as to create an inversion of Exon 10 in the presence of Cre. The reason for the focusing on Exon 10 from the mice is because Exon 10 is known to be necessary for CFTR function in humans and mice. Consequently, the deletion of Exon 10 results in creating mice that display similar phenotypic attributes to those that have CF. The second mouse model (Figure 1B) does not cause deletion of Exon 10 but rather contains an inverted Exon 10 that prevents a normal mRNA transcription and thus is inactive. However, when these inverted LoxP sites are catalyzed using Cre-recombinase, they reverse the inversion causing CFTR to be fully functional again (1).

The initial studies of these mice have been to express Cre in specific tissues and investigate the effects of losing or gaining CFTR function in one tissue or cell type at a time. The immediate goal of the study is to determine the optimum concentration of TM and the time span of treatment that will yield the highest rate of desired recombination. In order to determine the optimum conditions a reporter system was used in which the presence of TM induces the recombination of an inhibitory sequence, allowing a ubiquitous gene called ROSA to be expressed. This gene is responsible for coding for  $\beta$ -Galactosidase enzyme which can be detected through X-Gal staining (4). Therefore, the efficiency of TM induced recombination can be measured by the percentage of cells that turn blue after staining due to the presence of B-gal. The optimized conditions can then be used to induce recombination and thus inactivate or activate CFTR in the mouse.

The TM inducible system was tested in an in vitro system.



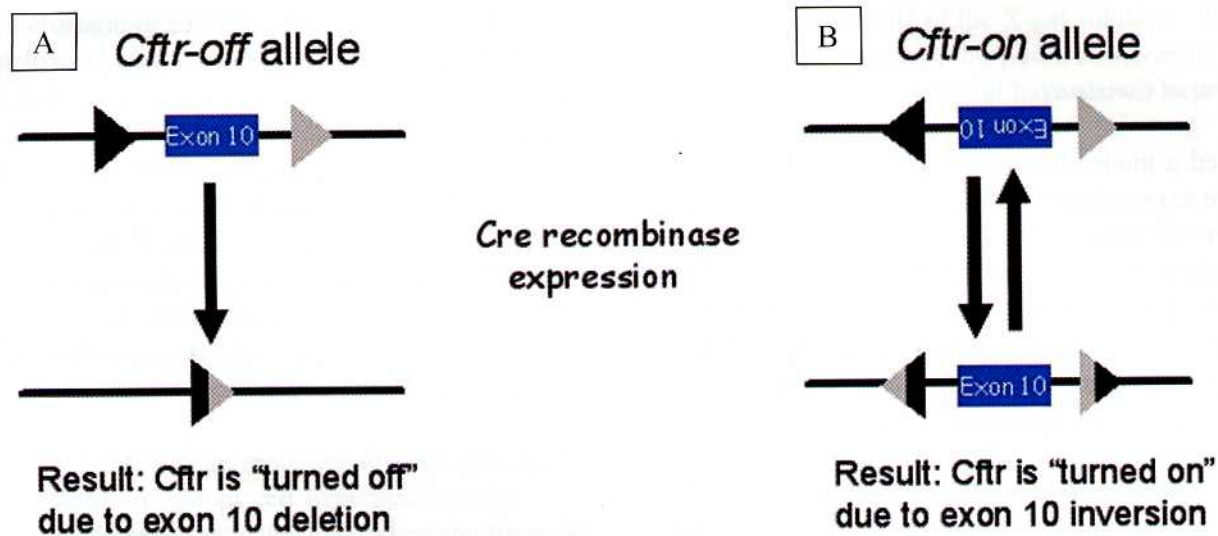


Figure 1: A schematic representation of the mechanism used to create knock out mice. Two small, 34 base pair sequences, called LoxP sites, are placed around Exon 10. A) Presence of the enzyme Cre Recombinase in similar orientation in a specific tissue causes the recombination of the floxed Exon 10, which is then degraded in the cell. B) An inverted orientation inverts Exon 10, but in the presence of Cre Recombinase the Exon 10 is re-inverted to its proper orientation, and activates CFTR function. (Courtesy of Dr. Craig Hodges.)

There are several advantages to conducting an *in vitro* examination at this stage of the study. First, it allows us to ensure that TM is administered uniformly to all the cells, instead of being available to a limited number of cells in an *in vivo* model. Second, it allows us to study CF pathogenesis at any given time point in the mouse life cycle, even prior to birth, because we are able to remove the fetus from the mother and examine the function of CFTR in undifferentiated fibroblasts. Third, it allows us to study CFTR function in a tissue while it is isolated from organismal mechanisms from other tissues. Finally, it allows us to maintain an ideal control because we can study the differences between treated and untreated cells of the same animal.

As stated earlier, individuals with CF often experience poor growth and survival, an attribute that has traditionally been attributed to malnutrition as a result of intestinal obstruction. Another common phenotype seen in CF patients is Goblet cell hyperplasia (abundance) (5). Goblet cells are mucus producing cells that are found scattered among other cells in the epithelium of many organs, especially in the intestinal and respiratory tracts. In the second part of the study we looked at a panel of conditional

mouse knock-out models that display varying levels of CFTR activity to examine the relationship of CFTR function in the intestine. A total of four models was studied. The first was the control showing 100% CFTR function. The second model was the hypomorph showing approximately 5-10% CFTR function. The third model, called the FABP, did not show any mouse CFTR activity – instead a human version of the CFTR (hCFTR) was expressed in the intestine. Finally, the fourth model was a complete KO of CFTR function.

It has also been seen that patients suffering from CF show an increased production of mucus (6). The reason for this phenomenon can be attributed to the systemic response to the lack of proper amount of mucus needed to lubricate the endothelial cells of organs. However, this overproduction of mucus feeds into the vicious cycle of obstruction because the malfunction of the CFTR protein results in increased viscosity of the mucus. Therefore, another attribute that was examined was the number of goblet cells in the intestinal tissue. The abundance of goblet cells was quantified and correlated to the frequency and severity of obstruction in the knock out animals.



## METHODS

### *Generation of Construct*

We crossed a mouse line that showed inducible Cre-recombinase expression to another mouse of interest, such as the turn-off mouse (Exon 10 flanked by LoxP sites), turn-on mouse (Exon 10 flanked by inverted LoxP sites), or the Rosa- $\beta$ -Gal mouse (negative operator flanked by LoxP sites). These crosses gave us offspring that were sensitive to the presence of TM and resulted in recombination of the flanked region upon TM administration.

### *Fibroblast Plating, Induction, and Staining*

At 12-14 days post coitum fetuses were removed from the pregnant mother. The developing brain and liver were removed from the fetuses, and the rest of the tissues were

minced. The tissues were allowed to digest in trypsin for 30 minutes. Following digestion, cells were plated. Cells were split into three wells several days later and plated at a concentration of 50,000 cells in each well on a six-well plate. Two wells were treated with TM at varying concentrations, while one of the wells was maintained as a control with no treatment. After 48 hours, TM was removed from the cells, and X-gal staining was performed. Cells that underwent recombination turned blue (Figure 2). A qualitative analysis was done to determine the percentage of cells that turned blue.

### *Recording Growth and Survival*

Growth rate and survival was recorded on each of the four strains of mice showing variable levels of CFTR activity. Data was accumulated on each mouse from birth till the 40th day of their life cycle. The new litters were weaned

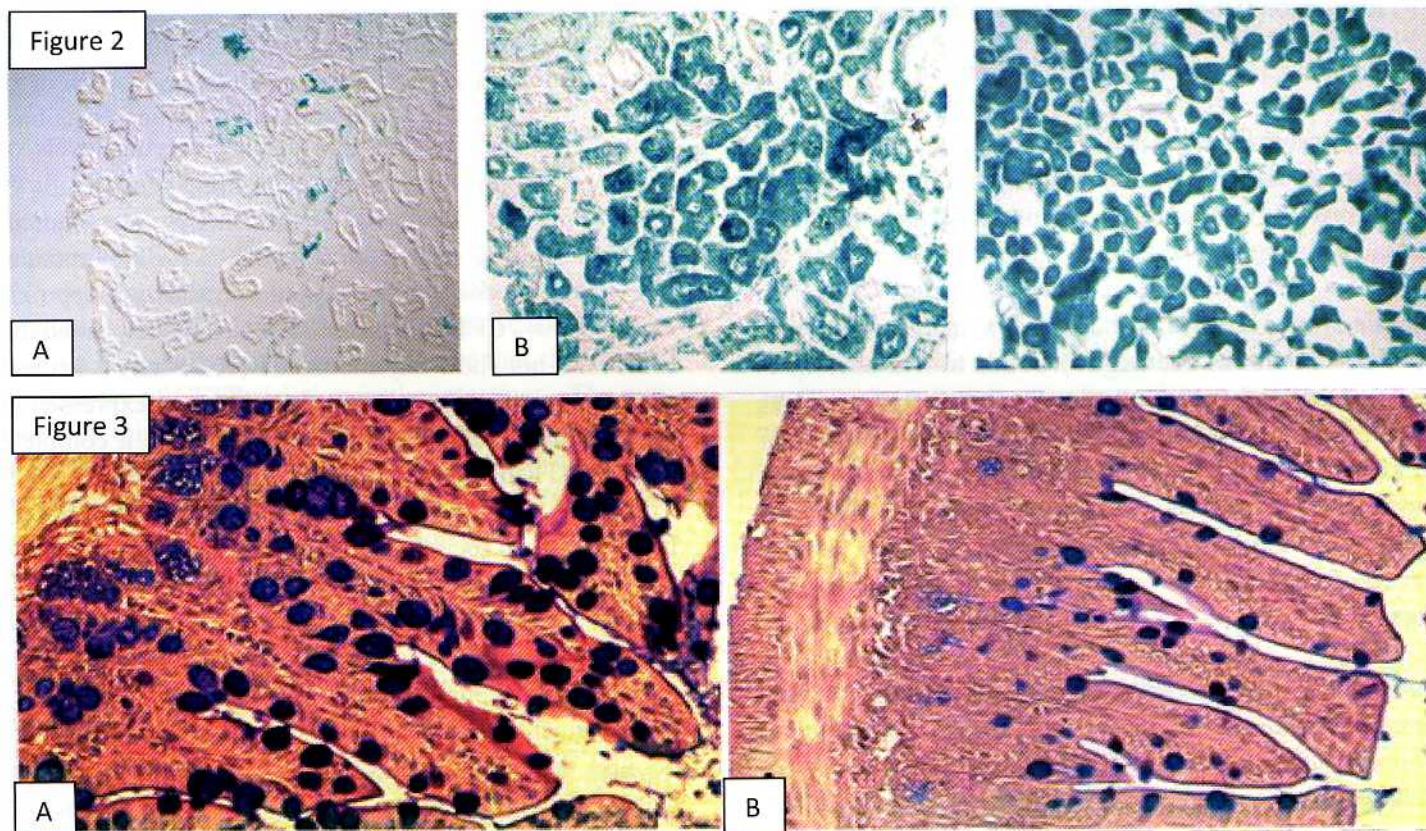


Figure 2: Renal tissue segments after X-gal staining. A) No TM treatment B) 3mg of TM treatment C) 9mg treatment of TM treatment. All treatments were performed for 48 hours (2).

Figure 3: Intestinal cross sections. A) An intestinal segment from the ileum of a CF mouse. B) An intestinal cross section of a wildtype animal. The number and size of goblet cells in wildtype animal is frequently lower. Only the cells on the periphery of the villi were counted.



from the parents' cage at day 20. Males and females were placed in separate cages. Growth was recorded every five days as a measurement of the animal's weight through this period. Survival was recorded with respect to the rate of mortality seen in the populace of a specific strain. A minimal ten animals were examined for each strain. Statistical analyses were performed to verify correlation between the observed attributes and CFTR activity levels.

#### *Gastrointestinal Histology – Quantification of Goblet Cells*

Paraffin-embedded sections (5  $\mu$ m) were stained with dye for the evaluation of goblet cell hyperplasia in the mice showing variable levels of CFTR activity. A thousand cells were counted from the peripheral lining of the intestinal villi (Figure 3). Goblet cells were included in the total of thousand cells; however, the number of goblet cells was also recorded to determine the ratio of goblet cells to epithelial cells. Varying sections from two different slides were examined in order to gain a wide sampling of the tissue segments. Statistical analyses were performed to verify correlation of CFTR activity to number of goblet cells for each strain.

## RESULTS

### *Tamoxifen Inducible System and X-Gal Assay*

Much of our work with the inducible system thus far has dealt with establishing a protocol that will yield reliable results. This process has encompassed a great deal of trial and error and has given us some preliminary parameters that we hope to build upon in the future.

By varying the concentrations of TM treatment we have established that the fibroblasts are unable to survive at TM concentrations above 1 $\mu$ M. 48 hours for recombination also seems to be an optimum time for treatment duration. Time points below this treatment period show significantly reduced recombination rates, and treatments longer than 48 hours have shown no significant increase in recombination. Longer durations of treatment can also lead to significant cell mortality.

We have also had to make significant modifications to our X-gal protocol, adjusting the time of the perfusion step

and adjusting the pH of the X-gal solution. The protocol has been inconsistent to this point; however, our modifications to the starting protocol have shown improvement in the results.

### *Growth and Survival*

We examined the growth and survival of the strains of mice that showed variable quantity of CFTR activity. Figure 4 presents the data for growth seen in the four strains of mice being studied. It was seen that the wildtype mice, showing 100% CFTR activity, grew the most (measured in grams). The complete KO mice grew the least consistently showing half the weight of the wildtype animals. The R117H and the FABP mice showed similar growth and survival patterns (Figure 5). They showed a significant ( $t < .05$ ) decrease in growth from the wildtype; however, survival was almost equivalent in these animals to the control group. A slight increase in mortality was seen around day 21 in all strains; however, in the complete KO survival decreased drastically around day 23. The survival rate decreased from approximately 85% on day 20 to 20% on day 26. This is compared to 93% survival in R117H, and 95% survival in both FABP and wildtype control on day 26.

### *Goblet Cell Number*

Cells from two slides were counted in order to quantify the percentage of overall cells that were goblet cells. For each animal, 1,000 cells were counted. T-tests were performed on the group data. A significant increase was seen in the number of goblet cells in the hypomorph as compared to the control group. The hypomorph showed an average of 222 goblet cells/thousand cells, whereas the control group showed an average of 157 goblet cells/thousand cells. The complete KO also showed goblet cell hyperplasia; however, no statistical significance was reached. Finally, the FABP showed a decreased level of goblet cell number compared to the control. Many of these groups do not have a large enough sample size at this point.

## DISCUSSION

### *Tamoxifen Inducible System*

It has long been established that Cystic Fibrosis is caused



by a mutation in the CFTR gene. Despite rigorous studies, researchers are uncertain of the primary and secondary manifestations that result due to direct loss of CFTR function. In order to distinguish some of these manifestations, Dr. Hodges has created mouse KO models in which we can delete CFTR function on a the function of CFTR in specific tissues by observing how these deletions affect the overall phenotype of the animal.

Along with studying the manifestations of the disease phenotype, it is also important to determine the pathogenesis of the condition. In order to accomplish this we have created a inducible KO system in which we can control the times in the mouse life cycle when CFTR function is either deleted or activated – referred to as turn-off and turn-on systems respectively. We have also created a reporter model that allows us to determine the concentration and duration of treatment that will give us the highest percentage of desired recombination in cells.

Thus far, we have used the reporter system to determine that the optimum concentration for TM treatment is somewhere between 500nM and 1 $\mu$ M. Concentrations below the lower limit do not seem to induce significant amounts of recombination. On the other hand, concentrations of TM breaching the upper limit become toxic to the cells. The reason for this toxicity can be attributed to the oncogenic qualities of TM. At high enough concentrations, TM can interfere with normal metabolic processes in cells, thereby, resulting in cell mortality.

We have also established that the optimum duration of treatment for the cells is 48 hours. Similar to concentrations, we must establish a time period that will give the cells an ample opportunity to respond to TM treatment; however, we do not cells to become over exposed to TM leading to death.

The optimization of this protocol would allow conditional activation of the CFTR gene. This approach will allow researchers to circumvent problems associated with germline ablation and early embryonic lethality caused by a standard knockout or over expression approaches, thereby allowing a more complete analysis of gene function. In future experiments, we aim to conduct in vitro studies of primary cells, which would allow us to examine the af-

fect on gene expression with the conditional knock out of CFTR function, thereby allowing us to gauge the effects of the gene in genome wide expression studies.

#### Growth and Survival

One of the most common phenotypes characterized in CF patients is poor growth and malnutrition. Traditionally this phenotype has been solely attributed to the lack of CFTR function in the intestinal epithelia. Lack of CFTR function in the intestines causes the buildup of viscous mucus and feces resulting in obstruction and the inability of the intestines to absorb proper nutrients. In order to validate, this idea we created a panel of mouse KO models that showed varying degrees of CFTR activity in the intestine. The purpose of this study was to determine the correlation between CFTR activity in the intestine, and growth and survival in mice.

As seen in Figure 4, there is a strong correlation between CFTR activity and growth for the mice that have full CFTR function throughout the body as opposed to no CFTR function in the complete KO. However, the hypomorph (R117H) does not clearly establish a correlation. The hypomorph is a strain that expresses 5-10% CFTR function in the organism, however, the strain does not show a close similarity to the wildtype growth as would be expected if the intestines were the sole cause of malnutrition. Therefore, attributing the whole growth phenotype to the intestines is not validated with our model. Our last model, the FABP, is essentially a whole KO, but it contains a human version of the CFTR gene in the intestines. The FABP showed a very similar growth phenotype to the hypomorph. It was interesting to see that restoration of CFTR function in the intestines still gave us a growth phenotype that was more similar to the complete KO than the wildtype. This data reaffirms our conclusion that growth phenotype is associated to other tissues besides the intestines.

Survival patterns showed some interesting results. As expected the control showed a very high survival rate, whereas the complete KO showed a drastic decrease in survival over time. By the time the animals reach day 30 of their life cycles, only 20% of the complete KO animals survive, as compared to  $\approx$ 95% survival in wildtype. This decline can be attributed a significant point in the mice life cycle in our study, because at day 20 the mice are weaned



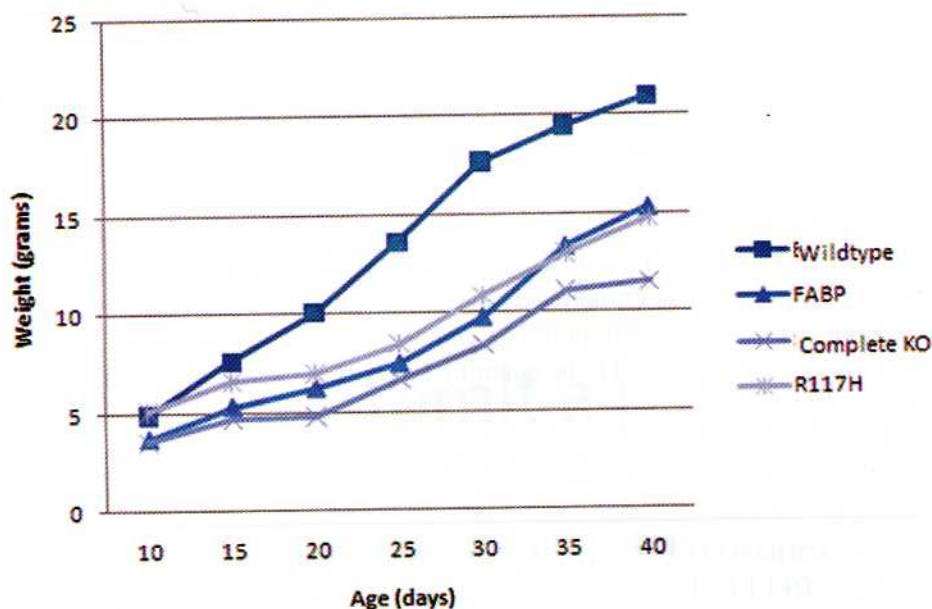


Figure 4: Weight of four different strains of mice showing variable quantities of CFTR activity. The four mice represented are the wildtype, the complete KO, the hypomorph, and the intestinal CFTR restoration. The wildtype animals with 100% CFTR activity show the greatest growth, whereas the complete KO shows the least amount of growth. The FABP and R117H strains show similar growth attributes to each other, and they are closer to the CF phenotype than the wildtype phenotype (Courtesy of Dr. Craig Hodges).

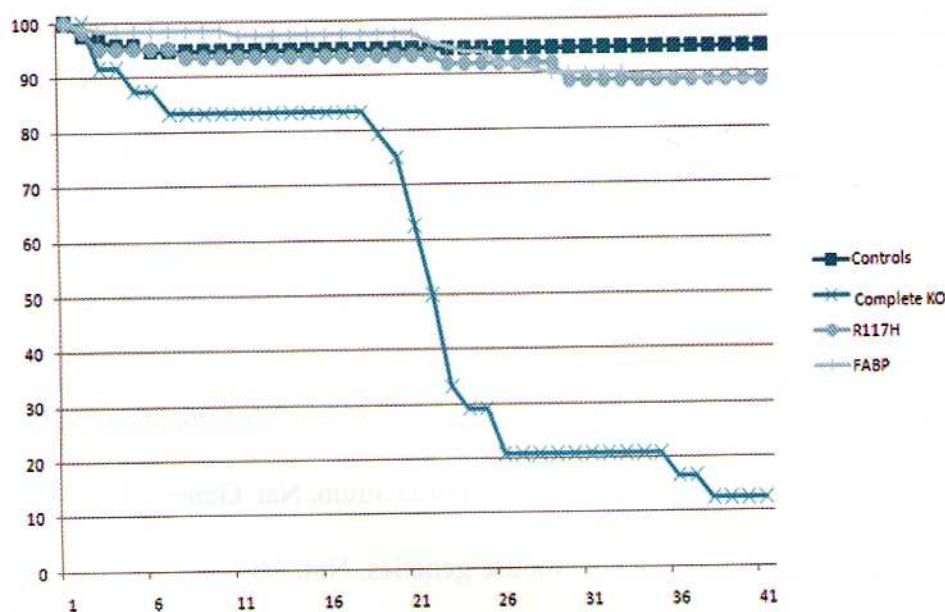


Figure 5: Survival of the four strains being studied. Survival is similar in the wildtype, the gur corrected FABP, and the hypomorph (R117H); however, there is a great deal of mortality in the complete KO around day 21 (Courtesy of Dr. Craig Hodges).

from the parent cages and placed in new cages separated by sex. We believe the sudden decline in survival is a direct result of the change in the type of food the mice consume. When the mice are with their mothers, they are able to be nurtured by the lactating female; however, in the new cage they must consume the solid food. This could exacerbate the obstructive condition in their intestines and lead to an increased death due to obstruction.

We also see that the R117H and the FABP model show a very high rate of survival – very similar to the wildtype. Therefore, we can conclude that there is a very strong

correlation between CFTR function in the intestines and survival. This phenomenon could occur due to sufficient restoration of CFTR function that could lead to prevention of obstruction; however, it does not address the issue of malnutrition.

#### *Goblet Cell Number*

Goblet cells are mucus producing cells present in the epithelial lining of various organs. A common phenomenon seen in CF patients is an increase in goblet cell number, a condition known as Goblet Cell Hyperplasia. The pur-



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pose of this part of the study was to determine if there is a correlation between CFTR activity and goblet cell number. The same strains of mice that were used to study growth and survival were used in this study.

In our model it was seen that there is a general trend of goblet cell hyperplasia in animals that had complete or partial CFTR activity deletion. However, aside from this general trend there is no definite relationship between the gradations of CFTR activity and goblet cell number. For example: it was seen that the complete KO showed a higher number of goblet cell number in the intestines than the wildtype. However, the R117H model, which has 5-10%

CFTR activity showed a significant increase in goblet cell number, even more than the complete KO. Finally, it was seen that the strain with hCFTR restoration in the intestines showed a lower number of goblet cells in the intestines.

At this point we are uncertain of the statistical significance of the data because most of the group data is composed of approximately three to four animals, amongst which the FABP only has one animal data. More animal intestines need to be quantified in order to verify the trends.

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