SCIENTIFIC TERRAPIN

VOLUME II
ISSUE I

THE UNIVERSITY OF MARYLAND'S
UNDERGRADUATE RESEARCH JOURNAL

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MARS
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Research
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SCIENTIFIC TERRAPIN

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MISSION STATEMENT

The University of Maryland, College Park is emerging as a top national research university. It is consistently named as one of the top fifty research universities and one of the top twenty-five public research universities in the nation. The university garnered $401 million dollars in research money in 2008, funding faculty and graduate investigation of our world from the myriad perspectives of scientists, sociologists, businesspeople, historians, and artists.

However, for the University to fully reach its potential as a top research institution, we believe that undergraduate students should play a more central role in the discussion, exchange, and visibility of research on campus. Currently many undergraduate students complete Honors Theses, Gemstone Theses and conduct research in labs on campus. Before now, though, there have been few outlets for students to share their work with the rest of the community and engage in the academic discussion and debate across specialties that sharing of research confers. It is this very "culture of research" that we wish to promote. *Scientific Terrapin* salutes student researchers for their initiative, their dedication, and their pursuit of knowledge and, thus, will fill this void by offering an outlet for student researchers to publish their work across all disciplines, including:

* The Life Sciences – biology, chemistry, biochemistry, and ecology
* The Applied Sciences – engineering, mathematics, computer science, physics, and geology
* The Social Sciences – economics, government and politics, psychology, business, and sociology

Scientific Terrapin provides a stepping stone for scientists across disciplines at the beginning of their research careers. We seek to provide undergraduate researchers a forum to present their work and receive peer and faculty review, as well as readership and recognition. We seek to connect student researchers with one another, so they might form intellectual partnerships and friendships, and so will sponsor workshops and presentations to not only encourage interdisciplinary discussion and debate, but to share research opportunities and practical advice for advancement in their fields. We herald the work of promising young minds and extraordinary mentors, allowing the community to learn about exciting research produced at the University of Maryland. And last, we hope to inspire students as they enter the university or continue with their education, to take the next step and join their fellow classmates in contributing to this culture of research and to claim their integral role in the vibrant and dynamic research at the University of Maryland.

CALL FOR SUBMISSIONS

We will be accepting submissions for the May 2011 issue of the journal until February 15, 2011. We encourage you to submit your work with a faculty mentor on campus, your findings from an internship, or an abridged Honors thesis or Gemstone paper in a scientific research article. The journal is accepting articles in the fields of life sciences, social sciences, and applied sciences. Submission details and guidelines can be found on our web site, www.scientifcterrapin.org.

Scientific Terrapin models our review process after professional journals. It is designed in a manner to provide authors rigorous and valuable criticism to help them learn about the scientific writing process and to improve the quality of their analysis. Upon submission of a manuscript, a qualified student editorial staff conducts an initial peer review. Components such as quality of analysis, scope of work, and quality of writing are evaluated. The manuscript is then returned to the author with a request for revisions. Revised manuscripts are then shared with University of Maryland faculty members in the field of the work in review. Faculty members evaluate the quality of the work and its contribution to the field. The recommendations of faculty members deem whether the work is published. Any required revisions are returned to the author to make changes. A final version of the manuscript is then prepared to publish in the journal.

ACKNOWLEDGEMENTS

We would like to thank our faculty reviewers for giving their time to review student submissions. We would also like to thank Dr. DuVinage and the Maryland Center for Undergraduate Research and Dr. Kaci Thompson and the Howard Hughes Medical Institute for providing support, guidance, and funding.

HHMI

MCUR MARYLAND CENTER FOR UNDERGRADUATE RESEARCH

NEWS & FEATURES

SCIENCE ON THE MALL

BY: JENNY WANG

White tents dot the length of the National Mall interspersed with the occasional space shuttle and pilot simulator. Children pinwheel down the dusty tracks, adorned with face paint and "I love Robots" stickers displayed prominently on their shirts. They tug at their parents' arms, fight for chance to get a picture with Sid the Science Kid and scream about astronauts. They also shriek happily about the magic of math, which is perhaps the most surprising thing of all.

The USA Science and Engineering Festival, the first of its kind in the nation, descended upon the National Mall from October 10th through the 24th. As a part of President Obama's Educate to Innovate campaign, the Festival was designed to showcase scientific innovations to thousands of American families and reinvigorate enthusiasm in science, technology, engineering and math in the nation's youth. The last weekend featured the Grand Finale Expo, which contained over 1500 different exhibits, 75 different stage shows, and celebrity "guests" like Bill Nye the Science Guy and Albert Einstein. Nearly 20 of these exhibits were organized by University of Maryland students and staff, with dozens more being manned by student volunteers. Their involvement in this celebration of science and engineering helped to attract thousands of guests, most of them inquisitive children.

HANDS-ON ROBOTS

One of the exhibits which drew consistently large crowds was sponsored by the University of Maryland's 4-H sponsored FIRST (For Inspiration and Recognition of Science and Technology) Tech Challenge (FTC) program. 4-H is a youth development program that was established in Ohio during the 1800's as an innovative strategy to introduce agricultural technology to the farming community and its influence has spread across the nation. Since its inception in Maryland, 4-H has sponsored pilot robotics programs in 18 counties. Arlene Lantz, a coordinator of the FTC program, said that she volunteered for the festival to draw more interest in the sciences. "Most of the students [working the exhibit] are from farms and carpentry. That was what they were going to do," she said, "but I think almost all of them are now interested in engineering and robotics."

It's easy to understand why students of all ages would be so easily lured into the robotic fields when exposed to robotic platforms like LEGO Education WeDo. Children crowded around a LEGO figurine, shrieking with laughter as the LEGO alligator snapped its jaws onto their fingers. Across from the tent, some volunteers were explaining the SuGO, or sumo LEGO, program to a crowd of enraptured children and parents. SuGO are light- and motion-sensitive robots that wrestle each other, mimicking Japanese sumo wrestlers. Two robots faced each other in a white ring, and then one abruptly moved forward, pushing the other out of the boundaries while the audience cheered.

Lantz was happy about the amount of foot-traffic that this exhibit received. "This is the slowest our exhibit has been," she laughed, as another wave of children shoved each other for a prime spot around the SuGO ring.

BE A SCIENTIST, SAVE TESTUDO

The College of Chemical and Life Sciences also had an exhibit at the Expo. Britney Hardy, a junior microbiology major, engaged visitors in a mock crime scene investigation to determine who attacked Testudo. She handed out DNA samples from the scene of the crime, and visitors tried to match them up to the DNA samples from some of Testudo's notable rivals: the North Carolina Tar Heels, the Duke Blue Devils, and the Wake Forest Demon Deacons. Those who correctly identified the nefarious assailant received a button that proudly proclaimed, "I'm a Terptective!!"

"Dr. Shields [an instructor with UMD's Cell Biology and Molecular Genetics department] was the mastermind behind the wall," Professor Edgar Moctezuma said before he flitted away to help with the DNA Beads activity.

Several UMD students manned the DNA Beads tables, where visitors created bracelets with their names in DNA codons. Children wrote out their names on small whiteboards. Underneath each letter of their name, they penned in the corresponding codon. Then, they strung adenine, guanine, cytosine, and thymine beads onto a bracelet, capped by a large turtle shell bead.

WHERE SCIENCE IS (EVERYWHERE!)

The UMD chapter of the American Society of Microbiology had several tents at the festival to educate visitors on the prevalence of microbes. Their most popular tent showcased rabies, Methicillin-Resistant Staphylococcus Aureus (MRSA), E. coli, T4 Bacteriophage, and swine flu in a trivia game. Children and adults alike crowded around, hoping to win a coveted stuffed microbe by answering a question correctly. Student volunteers Kelly Klein and Vy Nguyen, both microbiology majors, assisted at the event.

Klein, who had only been working for an hour, was already sounding a little hoarse. "There are tons of children mobbing me for questions. They all want a microbe. I've even had college students who answer wrongly insist that they're right. I just let them have a microbe."

Nguyen, on the other hand, was really making people work for the stuffed toys. When she got a huge group of people that wanted to answer a question, she led them away from the chaotic crowd and regaled them with fun microbe facts first. "Even though they really just wanted a prize, they all looked really interested," she said.

With the help of the UMD students and staff, microbiology and microbes have never been more popular at the Expo, drawing in fans of all ages. Likewise, science and engineering, which have always been rather intimidating fields for young students, were celebrated by brightly smiling cheerleaders at the Expo. Larry Bock, the creator and executive director of the festival, lamented the current condition of science and engineering in the United States. His purpose for bringing a science festival to the U.S. was to make science more accessible. Bock said that his hopes were that "people will look back and say, 'Gee, it was at the U.S.A. Science and Engineering Festival that I first got the idea to do [science].'" And if the ear-piercing enthusiasm resonating from the exhibits and mobile labs were any indication, Bock succeeded in his goal by inspiring many future scientists.

Terps Open New Chapter:

CLFS and CMPS Become College of Computer, Mathematical and Natural Sciences

By: Jason Albanese

On September 16, the University Senate approved the merger between the College of Computer, Mathematical and Physical Sciences (CMPS) and the College of Chemical and Life Sciences (CLFS). The new college, titled the College of Computer, Mathematical and Natural Sciences (CMNS), brings the core sciences together under the same college.

The merger aims to promote interdisciplinary research among the core sciences and coincides with the end of the terms of the deans of the respective colleges. Dean Steve Halperin, previously the dean of CMPS, served as interim dean for CLFS before the merger and now serves as interim dean for CMNS until his term ends in June 2011. The search for a new dean to lead the combined college to new heights is ongoing, and a search committee has been created to find a new dean to take over in Fall 2011.

The push for the merger began almost a year ago and progressed rapidly to a vote by all faculty, staff, and students of both CMPS and CLFS. Of the students, 57% voted for the merger while 37% voted against it and

6% abstained. Of faculty and staff, 74% supported the merger. These majorities pushed the merger proposition through the University Senate, ultimately leading to its approval.

Many within the college are optimistic about the merger, particularly in terms of research collaboration. Biology professor Charles Delwiche said, "It's just a little bit easier to justify collaboration if you're in the same college." Delwiche noted that projects requiring joint funding from two programs are easier to approve when researchers only need to convince one dean. Delwiche added, "It also increases the overall efficiency of the university."

Despite the merger, current research endeavors appear to continue as before and much of the college infrastructure has remained unaltered. While some have a favorable outlook on the effects of the merger, others do not see it as vital to improving quality or scope of research. Regarding interdisciplinary research before the merger, math professor Jeffrey Adams said that he could always collaborate with another department such as biology if he wanted.

As with any change, there may be potential complications. With the merger of the colleges, the problems faced by each college have also been bundled. The merger has left some staff members concerned about potential academic downsizing or cuts in funding according to Dr. Delwiche, though he hopes this concern is unfounded. As of yet, the merger has not resulted in any reduction in positions or financial cuts. Still, Delwiche noted, the structure of the two colleges previously had an unusual arrangement, with research and coursework headed by the college rather than by the various departments. "Although there will be growing pains, I think it's going to work out," he said in respect to the restructuring of the system. This sentiment is echoed by many members of faculty and staff – that the new arrangement will lead to a stronger university.

DR. WESLEY LAWSON'S ELECTRIFYING NEWS

By: Maia Werbos

What do a machine that prevents migraine headaches, a magnet that helps detect breast cancer, a non-invasive test for carpal tunnel, and a device to prevent self-injurious behaviors all have in common? No, they are not machines of the future that eradicate disease and suffering, but real-life medical devices Wesley Lawson, Professor and Associate Chair for Undergraduate Education in the Department of Electrical & Computer Engineering, works on every day to improve the lives of patients. Lawson entered the field of electrical engineering to help people and has continued down that same path to get to where he is today: teaching undergraduates and creating devices to improve the future of medicine.

As a high school student, Lawson witnessed the oil crisis of 1973 and wanted to work to avoid future energy crises. Thinking engineering could lead to the solution, he decided to go into electrical engineering. However, life took its course and Lawson instead landed in high-power microwave sources. Collaborating with researchers from Stanford and MIT, he worked for 20 years in this field. "I never quite made it [to energy]," he says. "But I came close at times."

But when Lawson got the opportunity to work on medical devices, he decided to switch his focus to those devices to make a difference in people's lives. His recent work centers on several different medical projects conceived by inventor Dr. Robert Fischell, the namesake of the Fischell Department of Bioengineering. Lawson designs devices based on Fischell's ideas.

The first device Lawson worked on aimed to cure migraine headaches. Fischell came to him with an idea for migraine sufferers who have "aura," that is, hallucina

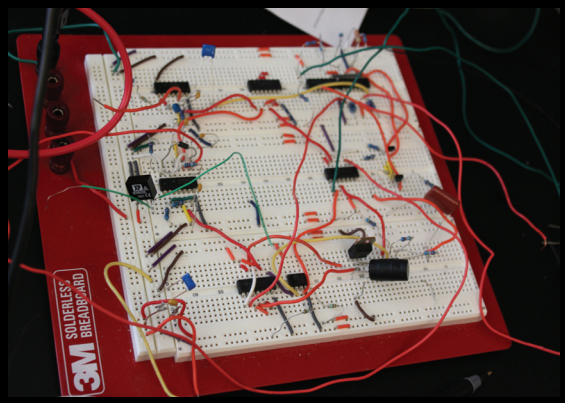
tions or other auditory or visual disturbances that occur up to 20 minutes before the headache starts. According to Lawson, migraines are an electrical disturbance in the visual center of the brain, a phenomenon known as cortical spreading depression. This wave of neuron activity travels very slowly, causing the hallucinations or other warning signals, and when it reaches the front of the head, the headache begins. To prevent the headache, Fischell proposed trans-cranial magnetic stimulation (TMS), in which a weak electrical current is induced in the brain using a rapidly changing magnetic field, to prevent the propagation of the electrical wave. The patient would use the TMS device as soon as they noticed anything strange in their vision or hearing, and hopefully, the device would prevent the migraine itself. Lawson's challenge was to cut down an existing 40-pound TMS device by 95%, to approximately two pounds. After several prototypes of the device, it was ready for clinical trials. Now Neuralieve, the company that took over the project, is working to get the device on the market, and Lawson has become a consultant for the project.

A second device, which is now in clinical trials, aims to make breast cancer surgery more convenient and cost-effective. In typical lumpectomies, where a tumor is removed from the breast, a mammogram has to be performed beforehand to identify the location of the tumor, and the surgeon often marks this location with a felt-tip marker. With Lawson's device, however, a small magnet, 1 millimeter in diameter and 2 centimeters in length, is inserted into the tumor before surgery. During surgery, the device detects the magnetic field emanating from the tumor and makes beeps of various pitch depending on how close the pointer is to the magnet. This allows the surgeon to locate and remove the tumor quickly and accurately. The results of clinical trials so far have been promising. After the

LAWSON WITH MAGNET DETECTOR *Dr. Lawson demonstrates the magnet detector for a device that improves breast cancer surgery. Even when the tiny magnet is hidden in his palm, the device detects it easily.*

next trial, which will have hundreds of patients, the device will go to the Food and Drug Administration for approval.

Perhaps the most controversial of the devices Lawson has worked on is a self-injurious behavior device: it prevents patients from deliberately hitting their head by re-training them with electric shocks. Hitting one's head against a wall or other objects can be a symptom of behavioral diseases such as autism; it can be very dangerous, leading to concussions, skull fractures, loss of consciousness, or intracranial hemorrhage. But social acceptance of the device has proven to be difficult, because it is based on aversive, on now people didn't even dream about when I was in high school. I've just gone to where my interests and position have allowed me to go, and right now I'm very happy." or punishment-based, therapy. The device, intended to be worn on the head, has a built-in accelerometer that detects when the patient is hitting his head and produces a very small current through his body. After wearing the device for some time, the patient will stop hitting his head, because of the unusual pain of the shock. Many view this method as an ethical challenge, especially in cases where patients are minors and their parents make the decision to give them the device. Lawson, however, believes it is appropriate in many cases, because it reduces the risk of long-term harm in patients for whom nothing else has worked. "Scientifically, it is known to



CIRCUIT FOR SIBs *This is a test circuit built by a student for the newest version of the self-injurious-behaviors device. Soon, it will be transferred to a more usable form, on a printed circuit board.*

be completely safe... You can have pain [that] is not going to cause any damage, or you can have pain [that] is going to cause a great deal of damage," he says.

So far, the public has not agreed with him. The current plan for the project is to get input from the community and incorporate more safeguards into the device so that it is acceptable. Lawson truly believes that the device can make a difference in people's lives, and so he is willing to do "whatever it takes... to get it out there and to see if we can't do some good with it."

In fact, Professor Lawson is so invested in his medical projects that, when working on a less painful way to test for carpal tunnel syndrome, he actually tried out the current diagnostic method and felt the pain himself.

"I went up to a hospital up in Baltimore where they stuck these electrodes [onto my palm and lower arm] and gave me the shock," he says. "It does hurt quite a bit." But he views these experiences as "fun" in a way, because they allow him to understand the kind of impact his work is having.

Lawson has had a long history at the University of Maryland, culminating in his current position as a professor. "I came here in '76 as an undergraduate, [and] I never found a way out," he says. He obtained two bachelor's degrees in math and electrical engineering, as well as a master's degree and Ph.D. in electrical engineering, all from the University of Maryland. He served as an undergraduate teaching fellow and a graduate assistant. "I guess that's when I really started thinking about this idea of how important it is to educate," he says of his time as a teaching fellow. He wants to make a difference not only for students, but also for all the people whom his students later impact.

Lawson's advice to students pursuing research is to start as early as possible. "You should just go out and look for what you think you're interested in, and then go for it," he says. You never know where you might end up, he reflects. "In high school, I didn't say, 'Oh, I want in 30-some years to be working on medical devices.' But technology changes very rapidly, and a number of things that I work on now people didn't even dream about when I was in high school. I've just gone to where my interests and position have allowed me to go, and right now I'm very happy."

NEW VERSION OF MIGRAINE DEVICE *A smaller, lighter version of a device to prevent migraine headaches. When the migraine's warning signs appear, the patient places the curved side behind their head and turns it on to dissipate an electrical signal in their brain.*

Plant Sciences Professor Receives National Science Foundation Grant

By: Niklas Berry

Dr. Priscila Chaverri, Assistant Professor in the Department of Plant Sciences at the University of Maryland, has received a $650,000 grant from the National Science Foundation to fund her work on South American Leaf Blight (SALB), an organism the United Nations has classified as a "potential biological weapon of mass destruction." Chaverri's job is to discover, catalogue, identify, and scientifically name fungi. Over the past few years, Chaverri and her graduate assistant have worked on analyzing and controlling SALB, a fungal disease that has infected rubber trees in the Amazon Basin and has potentially devastating consequences for the trees and the economy. According to Chaverri, if this disease spreads to Asian or African rubber plantations, it will affect millions of workers. In partnership with the Smithsonian Institution and a laboratory in France, Chaverri's lab is investigating a specific fungus that will be useful as a biocontrol agent in combating SALB. Because typical fungicides and pesticides have been ineffective against SALB, she hopes that the biocontrol agent will change and "coevolve" with the disease and still be effective over time. Chaverri encourages students to pursue research opportunities and get involved in research projects. When she was a student, Chaverri said she volunteered for many different projects because she wanted to gain experience and to build a competitive application for graduate school. She said that if a student came to her with a resume that listed a lot of research experience, she would choose that student over another student with a higher GPA and no experience. Having research experience, Chaverri believes, shows passion. As Chaverri said, "If an undergraduate student wanted to volunteer and come out to the field with me, they'd be welcome to come along." However, she noted, "It's tough to get people interested in mycology [the study of fungi] unless some sexy project comes along." For students who are interested in fungi or fungal diseases, the SALB project may indeed be a sexy project.

APPLIED SCIENCES

CRATER RETENTION AGES INSIDE AND OUTSIDE THE PROPOSED DICHOTOMY-FORMING BOREALIS (MEGA-) BASIN

LAUREN N. WOOLSEY
& DR. HERBERT V. FREY

ABSTRACT

Using populations of both visible and buried impact basins gives a more accurate crater retention age for any terrestrial planetary surface. On Mars, buried impact basins are found both in topography from the Mars Orbiter Laser Altimeter (MOLA), as Quasi-Circular Depressions (QCDs), and in crustal thickness models, we see them as Circular Thin Areas (CTAs). These features should be added to visible crater counts to derive the best crater retention age for the crust. The crustal dichotomy on Mars separates the smooth northern lowlands from the heavily-cratered southern highlands, and the proposed Borealis impact is a leading explanation for the origin of the dichotomy boundary. A study of several regions both along the boundary and further from it shows similar crater retention ages, suggesting the proposed Borealis mega-impact may have been global in effect.

INTRODUCTION

Mysteries surrounding Mars have slowly been solved, but one of the most important still remains: the origin of the crustal dichotomy that separates the smooth northern lowlands from the heavily cratered southern highlands. Images of Mars show a clear difference in surface crater populations between these two regions, but with the addition of buried impact structures, the crater population densities of the two regions are much more similar. High-resolution (64 pixels/degree) topography from Mars Orbiter Laser Altimeter (MOLA) has revealed quasi-circular depressions (QCDs) that have been interpreted to be buried impact basins[1,2]. A crustal thickness model that takes into account gravity measurements from Mars Global Surveyor[3] was used to find circular thin areas (CTAs) which likely represent more deeply buried impact basins than can be seen in topography[4]. Examples of both of these structures are shown in Figure 1. More recently, gravity data from Mars Reconnaissance Orbiter has allowed scientists to produce a crustal thickness model with much higher resolution[5], which

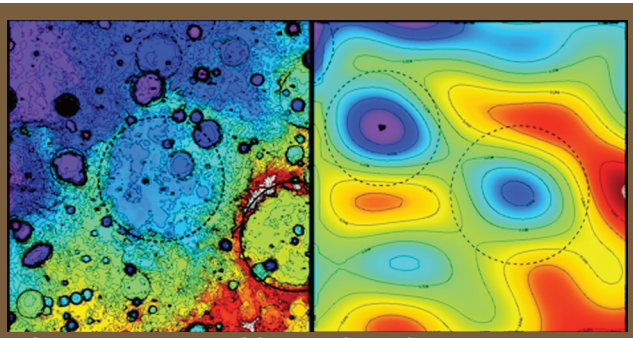


FIGURE 1 *Examples of QCDs and CTAs. On the left, a large QCD is shown in the center of the figure. At right, two strong CTA signatures are visible in the crustal thickness model.*

has greatly improved the discovery of CTAs[6].

Previously, and again more recently, a "Borealis Basin"-forming impact was suggested to explain the hemispheric dichotomy on Mars. This theory[7] states that a giant impact resurfaced the entire northern hemisphere of the planet, and the dichotomy we see today represents the remnants of the crater rim the impact created. The basin is so named because it lies in the northern hemisphere of Mars. The diameter of the original proposed circular impact crater is roughly 7,700 km, but more recent studies[8-10] suggest that a larger, more elliptical shape better explains the shape of the dichotomy boundary. This ellipse has a major diameter of 10,600 km and a minor diameter of 8,500 km[9]. If the Borealis Basin is the correct explanation for the dichotomy boundary, it would be the largest identified impact in the solar system.

In this study, we define areas along the boundary to compare the crater retention age both inside the basin and outside its rim in order to determine whether or not there is a significant difference between the highlands of Mars and the lowlands, where the proposed mega-basin would have formed. A difference in these ages would provide evidence against this theory because an impact of such magnitude would create an ejecta blanket that would resurface much of the terrain outside of the impact basin.

DATA COLLECTION & ANALYSIS

Before collecting data, we had to determine the areas to study. Different factors must be taken into account, including volcanic activity, previously recognized large basins, and proximity to previous studies. We selected two more or less "typical" boundary regions that show the sharp difference between the northern and southern hemispheres and compared them to a more anomalous region. This region, Arabia Terra, is a unique section of the dichotomy boundary, because rather than a sharp separation between lowlands and highlands, there is a gradual slope. The entire area is shown in Figure 2. There have been previous studies of this region[11] and we compare our previous study results to regions directly adjacent to the dichotomy rim. For the two typical regions, we chose sections along the boundary on either side of the Isidis Basin: one in the Amenthes region, and one in Ismenius Lacus. We avoided the Isidis basin and the volcanic regions of Elysium and Syrtis Major because the terrain in these loca

"DICHOTOMY WE SEE TODAY REPRESENTS THE REMNANTS OF THE CRATER RIM."

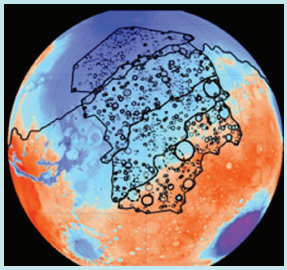


FIGURE 2 ARABIA TERRA DATA SET *A global map of the area, along with the proposed Borealis Basin running through the whole study.*

tions have undergone degradation and resurfacing processes that mask the true nature of the underlying surface. Beyond these border regions, we also tried to find some undisturbed regions in the lowlands and further into the highlands, but major basins such as Hellas, Acidalia and Utopia made this difficult. Each of the studied regions have unique characteristics and will be discussed in detail below.

In each region, the methods for discovering and evaluating buried impact basins were the same. Using the program GRIDVIEW12-14 to represent topographical and crustal thickness maps as a 3D surface, we searched for buried impact structures in the study areas. The term buried here simply refers to the fact that these structures are not visible in optical images of the surface of Mars. This could be due to erosion of the rim, sediment placement inside the basin, or a number of other processes.

For the topography, QCDs were identified after a primary search of the area, and then each was assessed using four main criteria: 1) the diameter must be at least 45 km, 2) the shape must be approximately circular, 3) at least 50% of the rim must be discernible, and 4) the depth of the feature must be 50 meters or greater. Any QCD in the identified set that did not fit these general criteria was discarded because it did not show enough indicators that it represented a previous impact. CTAs found in the crustal maps had more flexible guidelines. The CTA must be roughly circular and only candidates 150 km in diameter and above could be considered due to the lower resolution of the crustal thickness model[5]. Many CTAs are also QCDs, and sometimes a cluster of smaller craters can appear as a CTA. In both of these types of cases, the CTAs were eliminated from our final inventory. In general, we find fewer non-QCD CTAs in the highlands than in the lowlands, as would be expected given the large amount of resurfacing and burial that has occurred in the lowlands.

A. Amenthes

The region studied here ranges in longitude between 263W and 217W and in latitude from 30N to 18S (Figure 3). The northern (lowland) section enclosed an area of 2.166 million km^2, while the southern (highland) section is roughly 2.391 million km^2 in area. Amenthes borders the volcanic region of Elysium and

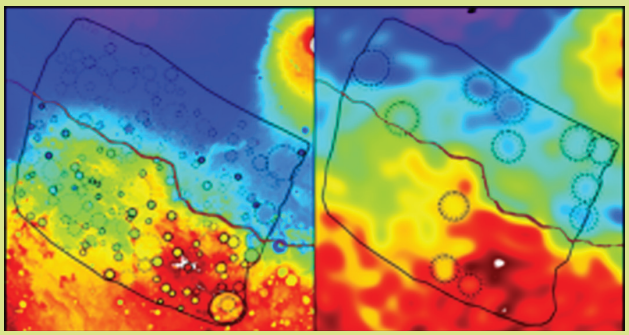


FIGURE 3 AMENTHES DATA SET *Region defined by black lines and separated by the dichotomy boundary, shown here in purple. QCDs plotted in topography on left, CTAs plotted in crustal thickness on right.*

the impact basins Isidis and Utopia. After our preliminary search and evaluation, the northern part of the Amenthes region had 78 members in the data set, nine of which were CTAs. The southern section had 105 members of its data set, only three of which were CTAs.

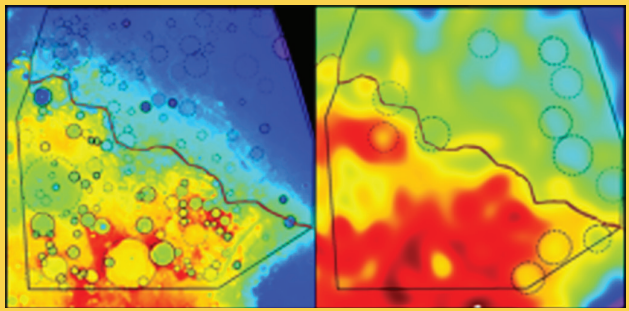


FIGURE 4 ISMENIUS LACUS DATA SET *Region defined by black lines and separated by the dichotomy boundary, shown here in purple. QCDs plotted in topography on left, CTAs plotted in crustal thickness on right.*

1. CTA uncertainties

In this region more than any other, the set of CTAs recovered from the crustal thickness model played a major role in the cumulative frequency curves. These curves represent the cumulative number of craters of a certain diameter within a given area. The 12 CTAs ranged in diameter from 200 km to 330 km, but the relatively low resolution of the crustal thickness model involves a measure of uncertainty in these estimates. We attempted to determine the possible maximum and minimum diameters for the CTAs in this region as well as a best estimate for the true diameter. The central diameters shown by thick circles in Figure 3 on the right are the values used in analysis, but the range of diameters is presented as a horizontal bracket (or a diameter "error bar") on the cumulative frequency curve for the region (Figure 5).

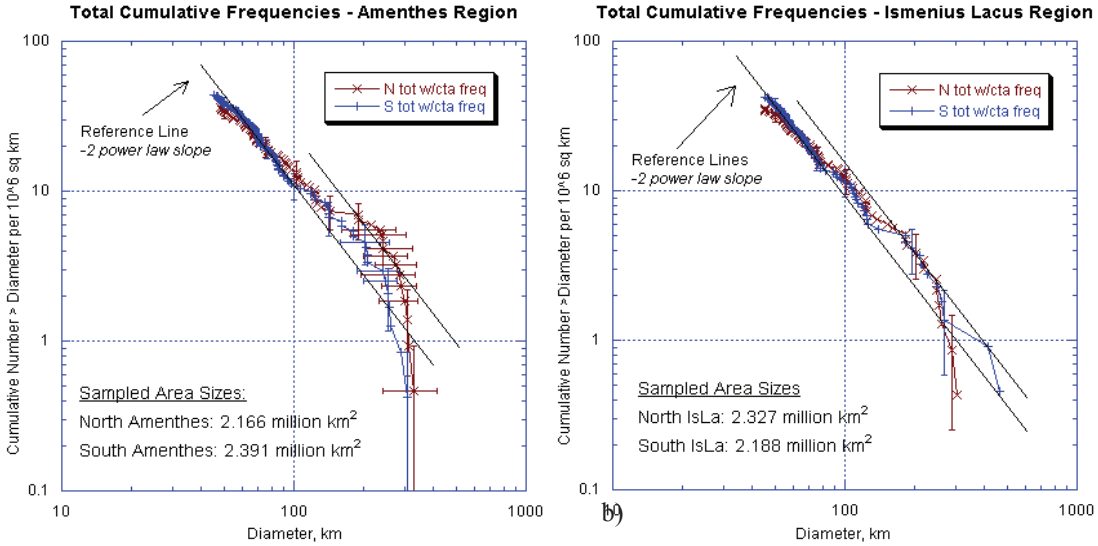


Figure 5: CUMULATIVE FREQUENCY CURVES FOR AMENTHES AND ISMENIUS LACUS
a) The Amenthes curves include both counting error (square root of diameter, represented by the y-axis error bars) and the uncertainty brackets on the CTA diameters mentioned previously. b) The Ismenius Lacus curves have an almost identical shape to each other, and they are within error bars at virtually all diameters.

With the uncertainties plotted, the curves for the northern and southern regions lie directly on top of one another within error bars, suggesting similar crater retention ages at both large and small diameters. At small diameters, both areas clearly have the same N(50) crater retention age. By N(50) age, I mean the cumulative number of craters of 50 km diameter and above within one million square km. The greater this age, the older the surface is, because the longer a surface has been exposed, the more craters it will accumulate.

B. Ismenius Lacus

This region lies between the areas we studied in Arabia Terra and Amenthes. It ranges between 320W and 270W in longitude and from 54N to 16N in latitude. The area of the northern half is 2.327 million km^2, and the southern half contains an area of 2.188 million km^2. Ismenius Lacus also borders the Utopia and Isidis Basins, on the western side of Isidis. The region is directly north of the Syrtis Major region. We found 76 QCDs and 7 CTAs in the northern (lowland) section of this region and 88 QCDs and 5 CTAs in the southern (highland) section. This region (Figure 4) contains some larger, prominent CTAs that are also QCDs in the southern region. The topography has a higher resolution, so the CTA is excluded from the data set and we use the QCD instead. Because the region borders on the Utopia Basin, the small-diameter QCDs are less abundant in the eastern part of the northern (lowland) section, having been buried by sediment from Utopia. CTAs in the area, which represent more deeply buried craters[4], reveal a similar overall crater density both inside and outside the Utopia Basin.

"TO DETERMINE WHETHER THERE IS A SIGNIFICANT DIFFERENCE IN CRATER RETENTION AGES..."

CRATER RETENTION AGES

For each region, cumulative frequency curves show the number of craters larger than a given diameter within a million km^2 area as a function of diameter. Crater retention ages (CRAs) can therefore be read off by the cu

Table 1. Visible-to-Buried Ratios

	N(50)				N(100)				N(200)			
	North		South		North		South		North		South	
	vis	*bur*	*vis*	*bur*	*vis*	*bur*	*vis*	*bur*	*vis*	*bur*	*vis*	*bur*
Lowlands	0.05	0.95	---	---	0	1	---	---	0	1	---	---
Amenthes	0.1	0.9	0.66	0.34	0.05	0.95	0.27	0.82	0	1	0.13	0.88
Ism.Lacus	0.11	0.89	0.78	0.22	0.05	0.95	0.6	0.4	0	1	0.67	0.33
Highlands	---	---	0.63	0.38	---	---	0.41	0.59	---	---	0.29	0.71

"THE BOREALIS BASIN THEORY FOR THE ORIGIN OF THE CRUSTAL DICHOTOMY IS CONTROVERSIAL..."

mulative number at a given diameter. We used 50, 100, and 200 km, but recognize that at smaller diameters, differences in local resurfacing may have a greater effect than at larger diameters.

A. Comparing Inside and Outside

Our main investigation is to determine whether there is a significant difference in crater retention ages inside and outside the dichotomy boundary, as some theories would suggest. For this specific investigation, we consider the Amenthes and Ismenius Lacus regions. Both lie directly on the boundary. The curves lie on top of each other within each region (see Figure 5). This means that crater retention ages for the lowland and highland sections of these regions are equal within error bars. The lowlands, therefore, are not younger than the dichotomy boundary but rather they have the same age, as would be expected if the lowlands and boundary were parts of a single, giant crater.

B. Ratios of Visible to Buried QCDs

As expected, the regions have varying degrees of burial. The table below compares the ratio of visible to buried craters found in the topography (CTAs are not included in these values, because they are found only at the largest diameter ranges). Here, lowlands and highlands represent regions further from

Table 2. Crater Retention Ages

	N(50)		N(100)		N(200)	
	lowlands	highlands	lowlands	highlands	lowlands	highlands
Amenthes	34 +/- 4	39 +/- 3	14 +/- 2	12 +/- 3	6.3 +/- 1.9	4.6 +/- 1.1
Ismenius Lacus	33 +/- 3	37 +/- 4	13 +/- 3	12 +/- 3	3.9 +/- 1.3	3.9 +/- 1.6

	N(50)		N(100)		N(200)	
	lowlands	highlands	lowlands	highlands	lowlands	highlands
N. of Arabia	41 +/- 3		16 +/- 2		5.3 +/- 1.2	
Arabia Terra	46 +/- 2	44 +/- 3	16 +/- 2	13 +/- 3	5.6 +/- 1.6	4.4 +/- 1.2
S. of Arabia		41 +/- 4		14 +/- 4		5.8 +/- 2.3

the dichotomy boundary. All lowland regions tend to have very few visible craters at lower diameters and none at D > 200 km (Table 1). Even in the highlands, there are fewer large visible features due to the ability of newer, smaller impacts to obscure and degrade older, larger ones. Amenthes has 82% buried impacts and Ismenius Lacus has less than half that ratio at D > 100 km, compared to more similar ratios at D > 50 km, which implies different efficiencies of crater obscuration for the two regions. Despite this, the regions end up with the same total N(100) value, implying the same crater retention age.

C. From one Region to Another

The most interesting result regarding the CRAs derived from this study is the fact that from region to region, the CRAs line up with each other within error bars. The following table shows the retention ages and uncertainties for each region at three different diameters. The values in the table are cumulative numbers and have no units. For a large diameter, the respective crater retention age will be smaller because there are fewer large impacts than small impacts. The three separate crater retention ages each overlap, within their error bars, in both the highland and lowland areas for all regions in the study. Arabia Terra, which consists of four regions, has been broken up into lowlands (North of Arabia), Arabia Terra proper (central two sections in Figure 2), and highlands (South of Arabia), and yet all subregions of Arabia Terra have similar CRAs for a given N() threshold. Note that the actual value given as a CRA does not have any physical significance without anything with which to compare. The results of our study are consistent with the idea that the dichotomy may be the result of a giant impact. CRAs on the boundary rim are the same, and they are similar to test regions interior and exterior to the boundary. An impact at the size proposed would certainly "reset" the crater retention age on its rim and in its interior, and these effects would likely extend to a large area outside the actual basin. Note that in Arabia, the CRAs listed (see Table 2) are, relative to each other, equal within error bars. Overall CRAs for the Arabia Terra region are expected to be slightly higher than our other studied areas, because it is more well-preserved than the other regions. Arabia Terra extends from well into the lowlands through the dichotomy boundary and well into the highlands, and still the crater retention ages are entirely consistent at larger diameters with our other data. This gives more evidence supporting a global resurfacing due to the proposed Borealis impact.

DISCUSSION

The Borealis basin theory for the origin of the crustal dichotomy is controversial, but it remains one of the few most recognized explanations for this mystery on Mars' surface. Recently, one of the key issues regarding the theory may have been resolved: the fact that the lowlands cannot be circumscribed by a circle[16] may be explained by the

new suggestion of a low-angle impact that would create an oblique basin[9-10]. This new resolution provides greater motivation for this project, as our findings lend support to this idea. The other major theory regarding the cause of the crustal dichotomy is endogenic, and requires a first-order mantle convection cell[17,18]. There is no reason to expect a similar crater retention age within and outside the influence of this mantle convection cell because if the mantle had been recycled to resurface the lowlands, the highlands would be unaffected. That our results show clear correlation on either side of the dichotomy boundary places doubt on an endogenic process. The crater retention ages derived in this study reflect a single event that resurfaced much of the Martian terrain, from the lowlands well into the highlands. Our study of crater retention ages for several small regions of Mars has proven useful in providing insight into the full extent of the event that created the crustal dichotomy seen on its surface. More comprehensive results would require a comparison of these localized regional studies with highland and lowland CRAs derived from a global population of all visible craters, QCDs, and CTAs inside and outside the proposed rim. This is a work in progress by M.A. Wyant[6].

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TERRAMECHANICS: TESTING WHEEL DESIGNS FOR PLANETARY SURFACES

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ABSTRACT

To better understand the surfaces, atmospheres, and geographic properties of planets in the solar system, planetary rovers were invented. On sandy, rocky terrain planetary rovers have engaged in loss of traction and wheel slippage.1 In order to investigate wheel-surface interaction, an automated test simulation system was designed and built in the University of Maryland Space Systems Laboratory. Using this system, experiments that calculated that the draw-bar pull at varying weights were conducted. Design properties were suggested for future planetary rovers, based on the trends produced among the tested wheel designs. The original draw-bar pull equation was manipulated for each of the aforementioned experimental conditions.

INTRODUCTION

One of the major issues surrounding wheel-surface interaction is the wheel-slippage issue. Presently, no valid explanations exist as to why rovers are unable to avoid wheel-slippage on planetary surfaces, specifically on Mars.[2] The primary goals for a planetary rover are the capacity to navigate in an unknown, hostile terrain, recognize and negotiate obstacles, deploy scientific instruments, and acquire samples from scientific targets.[2] Sojourner is a rover that was designed for the Mars Pathfinder mission with the distinct robust mobile capability to traverse hostile and challenging terrain.[3] Although the Sojourner made astounding landmarks as the first rover to successfully land and explore the Martian surface, it also experienced several problems related to navigating through the rocky, clay-like, sandy surface. In spite of all the issues that Sojourner faced while attempting to navigate through the intransigent Martian surface, the one that created the most frustration among the NASA Jet Propulsion Laboratory scientists and engineers was the issue surrounding wheel-slip-

page.[4] The scientists and engineers thought very critically about every move the Sojourner made because of the wheel-slippage the rover experienced. The terrain challenges that the Sojourner rover encountered on Mars were taken into significant consideration by professionals within the field, resulting in published papers on wheel-slippage. However, no applicable improvements have been released as to an improved and functional wheel design for the planetary rover. Due to several factors involved in space exploration, the wheel-surface interaction and concerns surrounding wheel-slippage represent the need for improvements in planetary rover wheel designs for future space missions.

Influencing better wheel designs for future planetary rovers requires conducting a series of three or four experiments in an attempt to reconcile several contributing agents associated with wheel-slippage. These agents consist of wheel design, wheel load, surface conditions, and design limitations. Currently, the focus is on the draw-bar pull produced from three different wheel designs tested on a simulated Martian-like surface. In an effort to build a working test simulation system and collect meaningful data in reference to the tested wheel designs, a set of hypotheses were derived. This study seeks to design and build a test simulation system that will allow for multiple wheel-designs to be tested. The design of the system will determine whether an accurate simulation system can be built. The development of this system will determine which procedures must be followed to obtain repeatable data and how the sensors and the test set-up are calibrated. Most importantly from an experimental stand point, this study will analyze whether the weight will affect the pull force necessary to make a wheel roll across a surface.

"NO APPLICABLE IMPROVEMENTS HAVE BEEN RELEASED AS TO AN IMPROVED AND FUNCTIONAL WHEEL DESIGN"

The successful development and calibration of the test simulation system provided an incentive to conduct further research regarding torque calculation and rover wheel design. In the near future the study is expected to analyze how surface characteristics affect the necessary pull force. In an effort to eventually obtain a torque calculation, an attempt to determine what configuration set-up causes the wheel to begin slipping was made. In a true effort to develop a rover wheel capable of traversing multiple terrain, future studies will determine whether a wheel can be designed to operate more effectively without slipping on a given surface.

In order to affect the future wheel design of planetary rovers, it is essential to propose solutions that produce applicable findings. These findings ensure that further research will be conducted by proposing an applicable solution that will impact future designs of planetary rover wheels.Additionally, this data can also be applied to earth-based wheel operated designs. As a result, designs such as wheel chairs, scooters, and cars can benefit from a design-based feature that allows for

functionality on soft surfaces, such as sand. Furthermore, for the past 27 years, planetary rovers have experienced wheel slippage issues on planetary surfaces.[4] If a solution could be proposed to limit the issues surrounding wheel-slippage, the rovers would have a less challenging time navigating throughout planetary surfaces. Not only would a valid solution ease navigational surface problems, but also it would permit the planetary rover the maneuverability, on these intransigent surfaces, needed to carry out the mission. The solution would serve to limit the setbacks NASA missions face based on planetary surface interference. In an effort to implement this solution, the experimental goal would be to make advancements toward a solution beneficial in limiting current setbacks.

PLANETARY ROVERS

The Viking to Mars Project of 1975 made history as "the first mission to land on another planet and return with both imaging and non imaging data over an extended period of time."[5] Since that time planetary rovers have been sent on missions to discover and investigate properties of planets in the solar system. On July 4, 1997 the Pathfinder, an interplanetary space craft, successfully landed on Martian soil containing the pyramid shaped "Mars station complete with camera, weather tower and instrument-laden rover named Sojourner, in an historic safe landing on the Martian surface at 1707."[6] Sojourner, the first successful rover to land on the surface of Martian soil, lasted 12 times its design lifetime of 7 days. After the success of Sojourner, rovers Spirit and Opportunity were sent to explore Mars in 2004. Spirit and Opportunity had a mission that consisted of obtaining geographical information on the surface of Mars. While these current rovers had an improved design lifetime of 6 months they each have far surpassed their design lifetime as they are still on Martian soil 6 years later.

COMPLICATIONS WITH WHEEL-SLIPPAGE

Spirit and Opportunity were originally sent to Mars to explore the geographical properties of the planet. These twin robots were developed to be geologists, and their task was to find answers regarding the history of water on Mars.[1] In order to accomplish this goal several factors had to be taken into consideration. One important factor is the wheel slippage or wheel slip-sinkage complication. The surface of Mars is very similar to the Moon; these surfaces are covered in regolith. For the planetary rover, these surfaces are considered challenging terrain.[7] "While moving on such a challenging terrain, severe slip-sinkage will occur for rover's wheels, making the vehicle decrease attractive performance,

deviate from scheduled path, and even get stuck in the soil. Slip-sinkage is an important failure for the planetary rover's moving on deformable terrain".[7] "In 2005; it took five weeks for the "Opportunity" Mars Rover to escape from the Purgatory Dune after getting stuck."[7] Although the planetary rover cannot combat every obstacle it faces on a planetary surface, future rovers could be better equipped to successfully traverse the terrain.

METHODS

The experiment was broken down into three phases and had an essential relationship with each componential phase. The design of the test simulation system was needed to complement the design of the wheel assembly cart which, in turn, needed to be correctly calibrated in order to collect accurate draw bar pull measurements. In the first phase of this project the test simulation system was built. It was later calibrated, which in turn allowed accurate measurements of the force required to roll a wheel along a sandy surface (draw bar pull). This system was initially designed to be assembled around the existing sand-box test facility. However, after deliberating and testing different designs in real-time, the design was modified, and the test system was configured to attach to the existing sand-box test facility. The sand-box test facility consisted of playground sand with additional rocks and hard objects added to simulate a challenging terrain. The design also entailed some adjustment capabilities so that dimensional modifications could be made; if necessary, for future testing. For the purposes of this experiment, the sand was approximately two feet in depth. Additionally, after the test simulation system was designed and assembled, it needed to be calibrated in order to accurately obtain force measurements during the testing. The test assembly was calibrated by designing a cross bar that would allow the smoothed surface to be duplicated under multiple trials. The next phase of the project was to design and build a wheel assembly cart. The wheel assembly cart was a two-wheeled cart designed with an axle that ran underneath the cart for an even weight distribution. The cart was designed so that it could be easily attached and removed from the test simulation system. This design provided the modifiable nature which was useful so that different wheel configurations could be mounted and tested. It also provided space so that different weights could be added to load up the wheels as they were being tested. Data was collected during the final phase of the preliminary project to search for interesting trends. This was completed by measuring the results of dif-

"FUTURE ROVERS COULD BE BETTER EQUIPPED TO SUCCESSFULLY TRAVERSE THE TERRAIN"

ferent wheel designs, loaded with different weights, and rolling it along known sandy surfaces. Data was collected and recorded for each configuration. Data was collected using lab view software; a force gauge transmits to a force collection device. As a result of the data suggesting interesting trends, new configurations will be tested in the future.

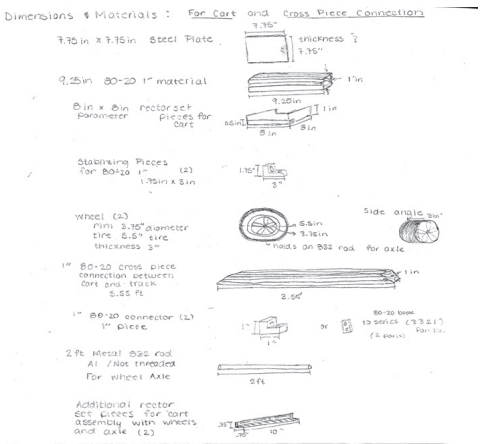

Figure I. Initial sketches

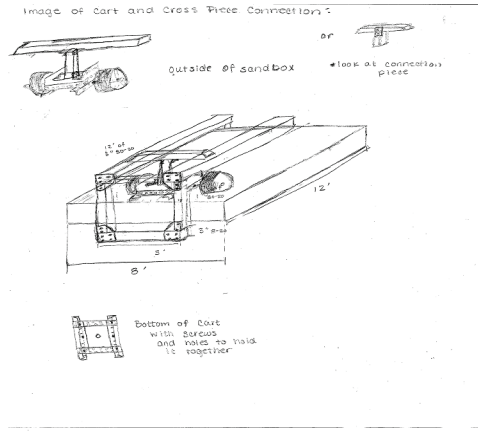

Figure II. Initial sketch of the Test Apparatus

My initial sketches represent the material used to build a functioning apparatus (Fig. I). The sketches were altered upon the completion of the functioning test apparatus (Fig. II).

In the data collection process, three trials were conducted, a series of six weight conditions were comprised in order to obtain meaningful data. The weight conditions initiated at zero and ended at five pounds. These conditions were developed in order to compare the draw-bar pull force for each of the tested wheels under every considered weight condition. The weights tested played essential roles on the accuracy and precision of the data collection process. Three different wheels were tested, each having different treads and wheel widths. Variation within the tested wheels allowed for very interesting results. Each wheel type was tested under the six weight conditions. The differences in wheel widths allowed for data analysis in comparing the wheels and the depth of the wheels treads, under the weight conditions represented.

RESULTS

A series of six weight conditions were comprised in order to obtain meaningful data. The weight conditions initiated at zero and ended at five pounds. Under each weight condition three trials were conducted. The weights tested played essential roles on the accuracy and precision of the data collection process. Three different wheels were tested, each having different treads and wheel

"GREATER DRAW-BAR PULL FORCE IS REQUIRED TO PULL THE WHEEL"

widths. Each wheel type was tested under the six weight conditions. The differences in wheel widths allowed for data analysis in comparing the wheels and the depth of the wheels treads.

The draw bar pull force was collected for each wheel under the six weight conditions (Table IV). The draw-bar pull force was measured in Newtons (N).

The depth of the tread for each tested wheel under the six weight conditions was measured (Table V). The depth was measured from the bottom of our test system to the bottom of the tread in the sand, and this measurement was recorded in inches.

Wheel-slippage occurs with four wheels two (1 in) and three (2 in). Slippage occurs in every trial for wheel two, although it does not occur throughout under the first weight condition (Table VI). In the case of the third wheel, slippage is not seen until the fourth weight condition (Table VI). In the fourth weight condition slippage does not occur throughout the entire trial which is denoted by /, but in the preceding weight conditions slippage is relevant throughout the entire trial. Slippage does not occur in any of the tested weight conditions for the first wheel (4 in) (Table VI).

The relationship between the force applied, the weight condition and the measured depth of the sand for each of the three tested

TABLE IV *The force under each tested condition for the three wheel types.*

	1 (N)	2 (N)	3 (N)	4 (N)	5 (N)	6 (N)
1	2.27	3.10	3.67	4.82	5.58	8.20
2	2.15	3.53	5.52	6.52	8.89	11.05
3	2.87	3.36	5.16	7.10	9.10	12.03

TABLE V *The depth of the tread for each tested condition for the three wheel types.*

	1 (cm)	2 (cm)	3 (cm)	4 (cm)	5 (cm)	6 (cm)
1	0.16002	0.19050	0.21336	0.31750	0.31750	0.33274
2	0.59436	0.71374	0.95250	1.03124	1.19126	1.27000
3	0.31750	0.39624	0.50800	0.63500	0.81026	1.11252

TABLE VI *The + denotes slippage and the - denotes no slippage. The / means Wheel-slippage does not occur throughout the entire trial.*

	1 (lb)	2 (lb)	3 (lb)	4 (lb)	5 (lb)	6 (lb)
1	-	-	-	-	-	-
2	/	+	+	+	+	+
3	-	-	-	/	+	+

wheels varies. The values recorded have an error of +/-0.02.There is an increasing relationship between the depth and the draw-bar pull force (Fig. I) for the first wheel. So as the weight condition increases the relationship between the force and the depth proportionally increases. Under heavier conditions the depth of the wheel in the sand increases in smaller increments. While the depth of the second wheel increases in a constant manner in large increments when compared to the first wheel (Fig. II). The third wheel experiences a drastic jump in the depth measurement under the 5 pound weight condition (Fig. III).

DISCUSSION

Based on the data collected, the research questions posed in the initial study can be answered. After several improvements and alterations a reliable test simulation system was created in the University of Maryland's Space System Laboratory. This system allowed for multiple wheel designs to be tested reliably. The data represented in Table IV represents the relationship between the draw-bar pull force and the wheel. It is evident that as the weight increases for each type of wheel, a greater draw-bar pull force

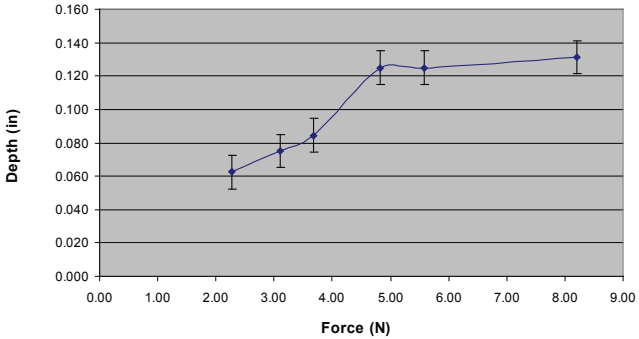

FIGURE III *Represents the force vs. depth measurement for the first wheel under each weight condition the sand depth is measured and recorded with an error of +/- 0.02.*

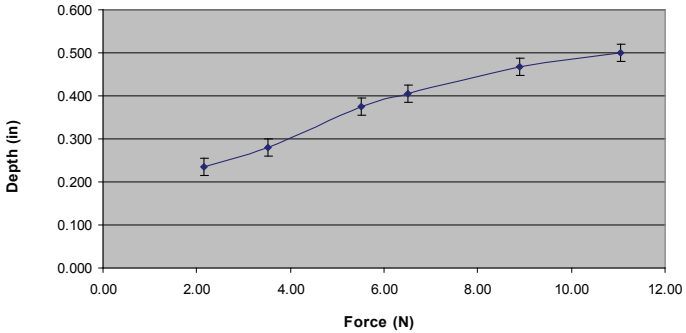

FIGURE IV *Measures the force vs. depth measurement for the second wheel under each weight condition the sand depth is measured and recorded with an error of +/- 0.02.*

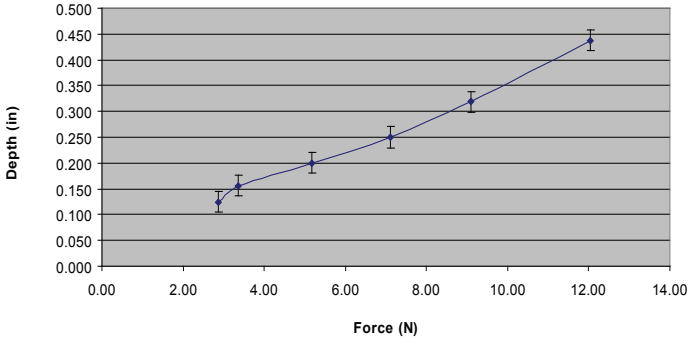

FIGURE V *Force vs. Depth measurement for the third wheel under each weight condition the sand depth is measured and recorded with an error of +/- 0.02.*

is required to pull the wheel though the sand. Furthermore, our data set was rich enough to answer some of the future research questions as well. The wheel configuration starts to slip when weight is added to the one inch wheel, the two inch wheel configuration also slips during and after the fourth weight condition (Table VI). There are two main conclusion that can be made in regard to the overall analysis of the collected data. First, the more weight added to the wheel, the more the sand will compact, and thus a greater draw bar pull force will be required to move the system and slippage may occur. In our cases for the narrower wheel types slippage did occur as the wheels had to bear more weight.

CONCLUSION

Several steps were taken toward the overall goal of this research which is to suggest a better planetary rover wheel design for future planetary rovers. The test system did not function properly with extremely heavy weights so a new test trial was conducted in an attempt to obtain meaningful and repeatable data. With this functioning test system repeatable data was collected, analyzed and interpreted. By understanding the relationship between the draw-bar pull force and the weight applied to the wheels, our research concluded that the more the weight added to the wheel, the more the sand will compact, which in turn requires a greater draw-bar pull force. Interesting trends were also unveiled between the depth of the wheel tread and draw-bar pull force. In the near future, tests that explain the relationship of wheels with multiple surfaces will be conducted. In addition, research that involves testing different wheel types as well obtaining the torque calculation will also be conducted. The information from these future experiments will provide much needed insight as to which wheels are most efficient for planetary surfaces. More importantly, these experiments will lend insight to the direction of our research. By conceptualizing this direction, the focus will be narrowed which will allow for a great leap towards the overall goal of developing a multi-surface transversal rover wheel.

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LIFE SCIENCES

EXAMINING VISCERAL LEISHMANIASIS, A ZOONOTIC PARASITIC DISEASE: A REVIEW

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ABSTRACT

The World Health Organization defines Neglected Tropical Diseases (NTD's) as diseases that affect the poorest populations often living in remote rural areas, urban slums, or conflict zones.[1] Transmitted by the phlebotomine sandfly, leishmaniasis is one such disease that is now found in 88 countries around the world, 72 of which are developing countries.[2] Largely a problem for those earning less than $2.00 per day, leishmaniasis debilitates 12 million people from leading productive lives.[3, 4] Visceral leishmaniasis (VL) is the most severe form of leishmaniasis and is fatal if left untreated. 90% of VL cases occur in Bangladesh, Brazil, Ethiopia, India, Nepal and Sudan, and VL has an incidence rate of 500,000 new cases per year.[5] While diagnosis and treatment are limited by cost and other variables, there are several effective prevention and control measures to contain the sandfly population. Moving forward, surveillance systems, health infrastructure, and education programs must be improved. Governments must work with international agencies, NGOs, private organizations, and most importantly the public to eliminate visceral leishmaniasis.

HISTORY

Visceral leishmaniasis (VL), also known as kala azar, is the most severe form of leishmaniasis. The initial discovery of this disease is uncertain, but many sources attribute the first reported epidemic to the 1824 outbreak in what was then Jessore, India, but today Bangladesh.Those infected experienced chronic fever, severe weight loss, emaciation, and dark discoloration of the skin, and eventually died from terminal dysentery or pneumonia. A few years later, the disease migrated to the Ganges plain and West Bengal from which it spread further to neighboring regions (See Figure 1). In 1862 VL reached Jageer, Bangladesh and wiped out most of the population within four years. The disease proceeded to kill 25% of the population of Assam, India, from 1875 to the start of the 20th century. Isolated cases continued through the 20th century, and recurring epidemics took place in Assam in 1918 and 1944. Due to this devastation, the disease was known as the "Assam fever."[6]

William Leishman and Charles Donovan are recognized today as the two physicians who

independently but simultaneously discovered the parasite responsible for the transmission of VL in the Old World. Leishman first encountered the parasite in 1900 while performing an autopsy on a soldier with a condition known as "Dum Dum fever." The soldier had experienced general debility, recurring fevers, anemia, muscular atrophy and excessive swelling of the spleen, and later died. During the autopsy, Leishman observed trypanosomes in the macrophages of the patient, and Irish physician Dr. Charles Donovan, who studied splenic aspirates of VL patients, later confirmed the discovery.[7] Major Ross, who named the organism *Leishmania donovani* after the two physicians, later discovered the link between the organism and the development of VL.[8]

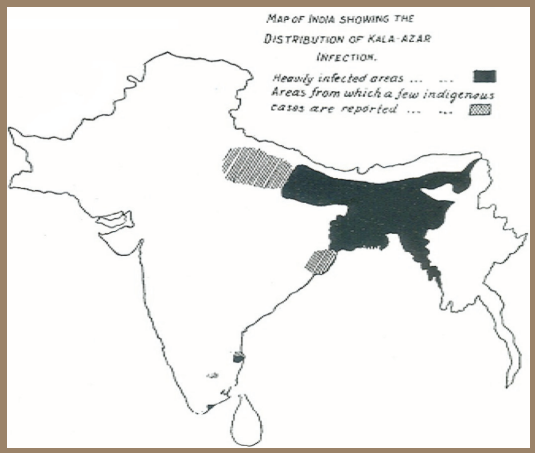

FIGURE 1 *Kala azar of the Old World in India, 1903*
Source: Thakur CP, Patna Medical College[54]

Leonard Rodgers investigated the transmission of VL and shed light on the life cycle of *Leishmania donovani*. John Sinton observed that the distribution of VL coincided with the distribution of the sandfly, *Phlebotomus argentipes*, and in 1940, the transmission of parasite to host was confirmed.[9]

Visceral leishmaniasis also affected those in the New World. In 1913, L.E. Migone reported the first case in Paraguay after identifying *Leishmania donovani* in a blood smear of an Italian who fell ill and died.[10] With time, other countries in South America reported their first cases.[11]

Mapping the Disease

Visceral leishmaniasis is no longer confined to the regions reported in its early history (See Figure 2). From 1996 to 1997 the number of confirmed cases of visceral leishmaniasis increased four-fold in Sudan. Treatment centers were consequently overwhelmed and drug stores depleted. The civil unrest caused a mass migration of people further carrying the epidemic to other countries. Brazil similarly experienced a sharp increase in the number of cases of visceral leishmaniasis due to migration of people, but the movement was within borders from the suburbs to the cities. Major epidemics with a high case-fatality rate in East Africa include Libo Kenkem, Ethiopia (2005); Wajir, Kenya (2007); and in the Upper Nile, southern Sudan (2009).[12]

Today the disease is widely known to be endemic in regions of the tropics and subtropics, and to areas that support the

habitation of species of sandflies from the Phlebotominae subfamily. Predominantly a rural disease, visceral leishmaniasis is

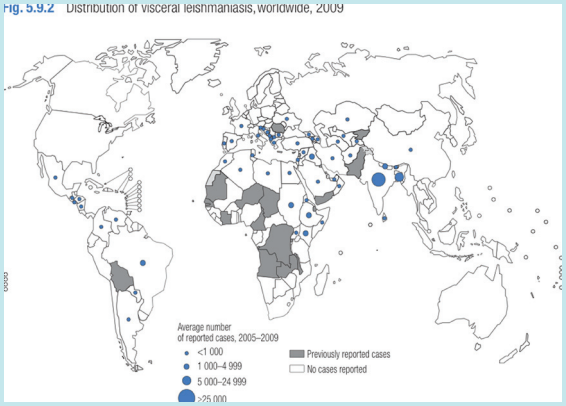

FIGURE 2 *Distribution of visceral leishmaniasis, 2009. Source: 2010 Technical Report, World Health Organization*[55]

found in 88 countries on four continents and causes about 500,000 new cases per year. 90% of cases occur in Bangladesh, Brazil, Ethiopia, India, Nepal and Sudan.[13]

Recent studies have revealed that estimates of morbidity and mortality are outdated, and it is unclear how the currently used numbers were derived.[14] This is largely due to the neglected nature of VL in the research and policy arenas. Leishmaniases infections are endemic in 88 countries, but are not "notifiable diseases" in 55 of these countries. As a result, the distribution of VL remains unclear today.

Biology of Visceral Leishmaniasis

Agent, Vector, Pathogenesis

Visceral Leishmaniasis is a parasitic disease that is transmitted by the female *Phlebotomus argentipes* sandfly vector. The disease agent is the parasitic protozoa *Leishmania donovani* or *Leishmania infantum*.[15] While the *Leishmania donovani* complex is common in East Africa and the Indian subcontinent, *Leishmania infantum* is in Europe, North Africa and Latin America. *L. infantum* infects mostly children and immunosuppressed individuals, and *L. donovani* infects all age groups.[16]

The lifecycle of *L. donovani* shows two distinct forms: a promastigote flagellar form found in the gut of the sandfly vector and an amastigote form, which develops in the mammalian host (See Figure 3). When the sandfly bites the host's skin, the promastigotes are taken up by dendritic cells and macrophages in the dermis and are transformed to their amastigote form. As amastigotes, the parasites are able to multiply and survive in phagolysosomes through a complex parasite–host interaction.[17] The amastigotes then spread throughout the lymphatic and vascular systems and infect other white blood cells in order to infiltrate the bone marrow and lymph nodes. At stage 5 as labeled in Figure 3, the sandfly takes a blood meal ingesting infected cells. In the sandfly gut, the amastigotes are transformed back to the promastigote stage, divide, and migrate back to the proboscis to infect another host.[18]

Transmission

The phlebotomine sandfly breeds in warm humid microclimates and is typically found in rodent burrows, termite hills, and organic remnants.[19] There are two major types of VL characterized by how they are transmitted. Zoonotic VL is transmitted from animal to vector to human, and anthroponotic VL is transmitted from human to vector to human. The major animal reservoir for zoonotic VL in humans is dogs.[20] Other animals that may serve as reservoirs include chickens, pigs, cattle, and horses as well as foxes, gerbils, and rodents.[21, 22]

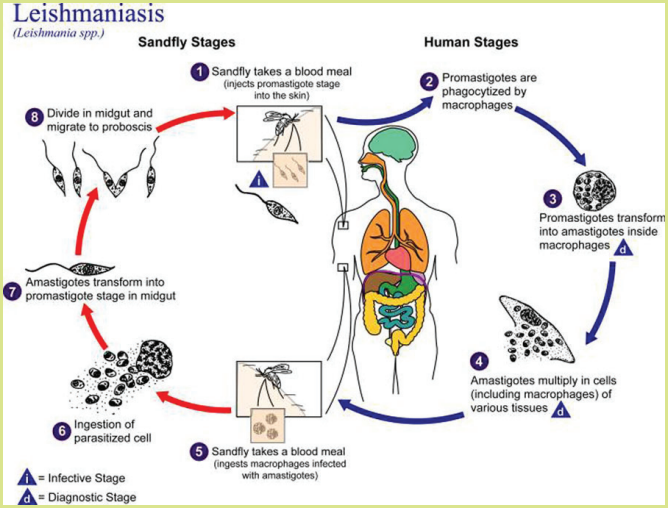

FIGURE 3 *Path of infection of visceral leishmaniasis.*
Source: Hailu et al; Centers for Disease Control and Prevention[56]

Post-kala-azar dermal leishmaniasis (PKDL) is a complication of VL that has been frequently observed in Sudan. It can also occur in immunosuppressed individuals in *L. infantum*-endemic areas. Characterized by a macular, maculo-papular or nodular rash, PKDL is highly infectious because the lesions contain many parasites which serve as a reservoir for anthroponotic VL.[23]

Furthermore, an increase in the populations of vector and reservoir can led to the spread of disease to previously "kala-azar-free" geographical areas. Climate change may lead sandflies to migrate to more favorable temperatures and proliferate. As the environment changes, the sand fly acquires new areas to inhabit, but this relationship must be investigated further for substantial conclusions to be drawn.[24]

Direct person-to-person transmission of VL, such as blood transfusion as well as sexual and congenital transmission, has also been shown. Syringe exchange amongst intravenous-drug addicts may also allow transmission of VL.[25]

Identifying the Disease

Clinical Presentation

After an incubation period that generally lasts between 2 and 6 months, VL infection leads to signs of persistent systemic infection including fever, fatigue, weakness, loss of appetite and weight loss. Further, the parasitic protozoa invade parts of the body causing enlarged lymph nodes, spleen and liver. Hypersplenism, a condition where red blood cells are destroyed rapidly

or prematurely in the spleen, is also common and leads to bleeding. Patients often experience fever with intermittent chills, fatigue, general weakness, and anemia.[26]

The clinical presentation can differ among endemic areas due to a combination of genetic and environmental components that are not clear yet. For example, enlarged lymph nodes are frequently seen in Sudan but are rare in other endemic areas. Another problem for identifying the disease is that symptoms can easily be mistaken for other febrile illnesses such as malaria and enteric fever.[27] Furthermore, even if the infection is transmitted, this does not always lead to clinical illness. Understanding the environmental and genetic risk factors that determine why two people with the same exposure to infection differ in susceptibility to illness could provide important leads for improved therapies.[28]

Symptoms and signs of bacterial co-infections such as pneumonia, diarrhea or tuberculosis can make it difficult to initially diagnose VL in a patient. The spread of the HIV infection in South America, Asia, and Africa has expanded to rural areas leading to HIV-VL coinfection. In Europe, access to antiretroviral therapy since the 1990s has reduced the number of cases of VL associated with HIV. Alternatively, regions without HIV treatment are seeing a rise in HIV-VL coinfection.[29]

Diagnostic Tests

Since it is difficult to assess patients by their physical symptoms, physicians and health workers must use more reliable laboratory tests to diagnose the patient. In order to aid control programs, the test should be able to distinguish acute disease from asymptomatic infection as well as active infection from cured infection. Both rK39 immunochromatographic strip test (ICT) and Direct Agglutination Test (DAT) are commonly used tests that are unable to make this distinction and show a positive result long after a patient has been cured. Alternatively, molecular diagnostic tools like PCR and real-time PCR are more sensitive and specific but are difficult and costly to perform. Other methods, such as a urine-based latex agglutination test must be improved for sensitivity. A simple, rapid, non-invasive, accurate and cost-effective marker of active VL is necessary to improve diagnosis of VL in the field.[30]

Current Treatments

High cost, toxicity, long duration of treatment regime, and slow progression of research and development continue to impede the way to effective treatment of patients infected with visceral leishmaniasis. For more than 70 years, the first-line treatment regime in most countries has been a lengthy course of injectable pentavalent antimonials. These drugs are potentially toxic, painful, and have become ineffective due to the development of drug resistance in parts of India and Nepal.[31] Amphotericin B or pentamidine is a more toxic second-line treatment that has been used in case a patient relapses.

Newly developed, liposomal ampho-

tericin B is highly effective, has almost no side- effects and is now the preferred first-line treatment for visceral disease; however, the drug is very costly and thus impractical for wide use in developing countries.[32] Miltefosine and paromomycin are other drugs that are distributed today. Miltefosine is the first oral drug so it is easy to administer, but it has several side effects including vomiting, diarrhea, and nephrotoxicity. Miltefosine is also very expensive. Paromomycin is a promising treatment due to minimal toxicity and low cost subsidized by a partnership between GlandPharma, a pharmaceutical company, and One World Health, a non-profit organization.[33]

Coupling drug treatments has provided protection from parasitic resistance as well as reduction in treatment duration and overall toxicity.[34] Current vaccine research has led to a promising "chimeric" vaccine containing three recombinant leishmanial antigens, but it is still in early stages of testing for safety and efficacy. Some suboptimal vaccines have been produced that may have uses in a therapeutic setting of disease treatment.[35] It is hoped that an effective vaccine will be developed in the next couple decades.

Prevention and Control Measures

Major prevention and control measures include reservoir control, vector control, and early diagnosis and treatment. Dogs are the main reservoir of *L. infantum* in zoonotic VL. Serological screening of dogs and killing sero-positive animals is debated as an effective control strategy. Treating sero-positive dogs is ineffective because dogs can regain infectivity weeks after treatment despite being clinically cured. The latest control approach is the use of deltamethrine-treated collars.[36] The WHO recommends sustained house-to-house spraying of residual insecticide as a powerful method to control the vector population.[37] In the 1950s India began using DDT to successfully reduce the sandfly population in the country. VL re-emerged, however, when the spraying campaigns were discontinued and resistance developed in sandflies in some regions. Spraying bed nets, bed sheets, windows, and window curtains can also prevent sandflies from entering homes and biting victims.[38] From 1999-2001, Medecins sans

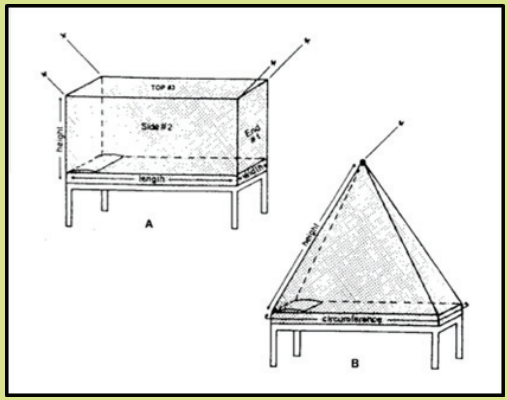

FIGURE 4 *Bed nets.*
Source: World Health Organization 1997 Manual[57]

Frontieres distributed 35,700 bed nets to 155 Sudan villages that were greatly affected by visceral leishmaniasis (See Figure 4). Within twenty months of the distribution of bed nets, the clinical cases of the disease had dropped by 59%. From this intervention, it was estimated that 1,060 new cases were prevented.[39] A study conducted in Nepal in 2001 also supports the use of insecticide treated bed nets as a protective factor for humans against infection.[40] Furthermore, early diagnosis and treatment are critical to protect both individual patients and communities. Untreated VL patients act as a reservoir for parasites and help transmit anthroponotic VL. The detection of PKDL patients is also critical to reduce the spread of disease.[41] While a vaccine is in development, the above described prevention measures are critical to implement in combination.

Social Aspects

As a neglected tropical poverty disease, visceral leishmaniasis is the most devastating amongst the poorest of the poor. Of the 88 countries with VL, 72 are developing countries.[42] Visceral leishmaniasis debilitates patients such that their ability to pursue work is impaired; if left untreated, the disease is fatal within two years of infection. Those affected by VL become poorer because of the high direct costs, such as diagnosis and treatment, and indirect costs, such as loss of household income.[43] For those who do start treatment, they often cannot afford to complete it. Coupled with persistent outbreaks of VL, lack of accessible treatment creates a continuous spiral of illness and poverty from which victims are unable to recover from.[44]

In Eastern Sudan, a study was conducted to analyze the socio-cultural aspects of visceral leishmaniasis among two tribes. The study observed 50 infected individuals, who were randomly selected from both tribes and interviewed. The majority of the respondents had an income of 500-7500 dinars (~19-29 USD). Only 62% of the respondents knew the name of the disease that inflicted them, and only 20% of the respondents knew the causative agent. The study also found that only 46% of the respondents sought medical treatment after 30 days of illness. 52% of respondents had trouble reaching a place of treatment due to lack of transportation, and 38.5% due to lack of money. When asked, 66% of respondents did not know the recommended methods of prevention.[45] All of these findings point towards systemic flaws that contribute to high VL rates among the poorest individuals.

The poor must thus be empowered with information by small community programs that can be installed and implemented by agencies in accordance with national policy guidelines and WHO recommendations.[46] In the case of guinea worm, another neglected tropical disease, behavior change programs were effective in remote rural areas. Vulnerable populations were given fine-mesh filter cloths to fit over clay pots they used to hold water, and nomadic groups were given

pipe filters that are easy to carry around. Both methods were appropriate to their life style and allowed people to drink water safely wherever they went.[47] As a result, cases of guinea worm disease reduced more than 99 percent since 1986. Even among poor and illiterate populations, positive behavioral change is feasible and health education works.

Since visceral leishmaniasis does not have any easy fix, it is critical that simple interventions are carried out by non-specialists, such as schoolteachers, village heads, and local volunteers in community-based preventive action.[48] This may be as simple as educating the poor to use insecticide treated bed nets.

The disease burden is made worse by stigma against VL in many affected societies. In India, the caste system prohibits the "untouchables," the lowest caste, from being treated. In Pakistan and Afghanistan, infected children are isolated, infected women are considered unsuitable for marriage, and infected mothers are separated from their children upon infection.[49] Other social factors such as ethnic clashes, disease ignorance and urbanization impede efforts to control VL. Due to the rapid growth of "mega-cities," where facilities for housing and sanitation are inadequate, transmission of VL has also increased.[50]

Moving Forward

As enumerated by Dr. Margaret Chan, Director-General of the WHO, the two major obstacles to eliminating visceral leishmaniasis are inefficient management of partnerships and limited health system capacity.[51] In other words, efforts must be unified and the appropriate infrastructure must be in place.[57]

In order to address these problems, the disease burden must first be defined by improved surveillance systems. As the leading technical authority on health, the WHO may best align the work of all partners with international standards, strategies, and recommended practices, in effect strengthening partnerships.[52] The WHO-Southeast Asia Regional Office has prepared advocacy pamphlets and posters to endorse the elimination of visceral leishmaniasis to decision-makers in the endemic countries. The World Health Organization continues to compile, synthesize, and distribute information for the international community to keep up to date on progress.

Endemic countries lack the resources, trained personnel, and transport to get patients from their homes to health facilities. With the assistance of wealthier countries, NGO's, and private organizations, new health facilities may be set up in endemic areas. Vector-control activities face challenges in terms of advocacy, human resources, logistics, and funds.[53] Whether in the form of raising awareness, fundraising, promoting R&D, or jumpstarting programs towards prevention and control, activities should be rooted in national efforts and capacities.

Visceral leishmaniasis is a devastating disease that requires more attention from the international community. It has caused social and economic stress for

millions of people, decreasing their quality of life and prolonging the cycle of poverty. Prevention and control measures coupled with research for improved diagnostic tests and treatment is necessary to eliminate visceral leishmaniasis in the future.

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