InterChange Newsletter

From the Regional Math & Science Center at Grand Valley State University

October 2014 | Volume 21, Number 6

FALL SCIENCE UPDATE: A CELEBRATION AND EXPLORATION OF QUALITY SCIENCE EDUCATION

The Regional Math and Science Center is hosting the annual *Fall Science Update* on Wednesday, November 19, 2014 from 8:00 a.m. to 3:00 p.m. at the L.V. Eberhard Center, located on Grand Valley State University's Grand Rapids campus.

This year's event theme is *"Celebrating Science Education: Past, Present, Future."*

Join us for the Fall Science Update as we feature this year's keynote speaker, Larry Fegel. *Full Story*

THE RMSC TURNS 25! CELEBRATE OUR HISTORY!

The Grand Valley State University Science and Math Center was established in the 1990- 91 academic year, but has a history of service to the K-12 schools and community that began in 1980. *Full Story*

MICHIGAN SCIENCE OLYMPIAD COACHING CLINIC

Attend the West Michigan Science Olympiad Coaching Clinic at Grand Haven High School on Saturday, November 8. Full Story

GET READY FOR MATH IN ACTION!

Math in Action presents lively and informative discussions of current issues in issues in mathematics education while providing an opportunity for practicing PreK – 12 teachers, prospective teachers, curriculum directors, and college and university faculty to share ideas, concerns, and resources. *Full Story*

TAKE PART IN EARTH SCIENCE WEEK 2014!

Held October 12-18, Earth Science Week (ESW) 2014 will promote awareness of the dynamic interactions of the planet's natural and human systems. *Full Story*

GENETIC UPDATE CONFERENCE FOR HIGH SCHOOL STUDENTS COMING IN NOVEMBER!

Join us this year as Dr. Sam Rhine presents his annual Genetic Update Conference at Grand Valley State University on Monday, November 10th, 2014. *Full Story*

CELEBRATE THE INTERNATIONAL YEAR OF LIGHT 2015 WITH SUPER SCIENCE SATURDAY!

In celebration of the International Year of Light 2015 and the Regional Math and Science Center's (RMSC) 25th Anniversary, the RMSC and the Physics Department at GVSU will be hosting *Super Science Saturday: The Wonder of Light,* a science extravaganza for the West Michigan community. *Full Story*

REGISTER NOW FOR THE SECOND ANNUAL MATH-TEAM-MATICS COMPETITION!

This fun and friendly competition will feature creative and engaging problems to bring the mathematical practices to life. *Full Story*

JOIN THE MICHIGAN ALLIANCE FOR ENVIRONMENTAL AND OUTDOOR EDUCATION CONFERENCE!

Join educators from throughout the state for the October 10-12, 2014 Michigan Alliance For Environmental and Outdoor Education (MAEOE) Conference! *Full Story*

VISIT FOSSIL DAY AT THE MICHIGAN STATE UNIVERSITY MUSEUM

Saturday, October 18, 2014. *Full Story*

2015 STATISTICS POSTER COMPETITION FOR K-12

The Department of Statistics at Grand Valley State University (GVSU), the Regional Math and Science Center at GVSU, and the Michigan Council of Teachers of Mathematics are pleased to announce the 2015 Michigan Statistics Poster Competition for K-12. *Full Story*

CALENDAR OF EVENTS

Calendar

CONNECTIONS FOR THE STEM CLASSROOM

TIMING IS EVERYTHING: Insights from Size-Dependent Changes in Organismal Form
Gary K. Greer, Associate Professor, Biology Department, Grand Valley State University *Full Story*

Fall Science Update: A Celebration and Exploration of Quality Science Education

The Regional Math and Science Center is hosting the annual *Fall Science Update* on Wednesday, November 19, 2014 from 8:00 a.m. to 3:00 p.m. at the L.V. Eberhard Center, located on Grand Valley State University's Grand Rapids campus.

This year's event theme is *"Celebrating Science Education: Past, Present, Future."*

Join us for the Fall Science Update as we feature this year's keynote speaker, Larry Fegel. With more than 40 years of science and environmental teaching in west Michigan, Fegel will talk about the changes, expectations and trends in science education since he began his career in 1969 at the Blandford Nature Center in Grand Rapids, Michigan. His talks is for both elementary and secondary teachers and will focus on highlighting many excellent examples of science education that have happened over the past 40 plus years as well as some of the frustration and challenges those teachers have faced. He will also share future possibilities and challenges for the next generation of science education.

In addition to the Dr. Fegel, over 30 hour-long breakout sessions will be presented by area educators. The Fall Science Update is designed to provide current information, hands-on activities, and collegial exchange through a variety of presentations on contemporary topics related to science and technology. The brochure and session registration form for *Fall Science Update* will be on our website by mid-October at www.gvsu.edu/rmsc or contact the Regional Math and Science Center at (616) 331-2267 for additional information.

Larry Fegel graduated from Grand Valley State University with undergraduate degrees in earth science, biology, and education. Within a few years, he earned his Master's degree in Fisheries and Wildlife from Michigan State University and went on to earn his administrative certification from Central Michigan University.

Larry's passion for science teaching and environmental education makes him outstanding in his field. His early accomplishments included; teaching education classes at Blandford Nature Center which included an opportunity to help start an outdoor education program for Grand Rapids Public Schools. Looking back, Larry believes one of the best programs he ever started was the educational farm at Blandford in 1974.

Several years later, he was hired by GRPS to start a new science program at City High School. He taught various science classes for many years there until he was called back to outdoor education as Director of Outdoor Education and Curriculum for Grand Rapids Public Schools. This eventually led him to a new position within GRPS as a science supervisor and curriculum director over the next twelve years.

In the fall of 1998, Larry took a position with West Ottawa Public Schools as an Assistant Superintendent for Teaching and Learning. Three years later, he retired from teaching K-12 education and was invited to teach Geology to undergraduate students at Grand Valley State University. For a period of nine years, he taught six different geology courses and once again, continued his work in environmental education by working as a program specialist and naturalist at the Outdoor Discovery Center and Macatawa Greenway in Holland, Michigan where he currently helps staff when needed.

Over his long educational career in public service, Larry Fegel has earned many awards and accolades. While teaching at City High School, he was twice named Educational Educator of the Year. He was also awarded Distinguished Alumni status and Outstanding Alumni Educator by Grand Valley State University and most recently honored by the National Association for Interpretation for his work in helping to develop programming at the Outdoor Discovery Center and Macatawa Greenway in Holland, Michigan.

The RMSC Turns 25! Celebrate Our History!

The Grand Valley State University Science and Math Center was established in the 1990- 91 academic year, but has a history of service to the K-12 schools and community that began in 1980. At that time, teachers connected to their favorite professor or department to arrange for student visits and campus tours. In 1983, the Science and Mathematics Division wanted to bring more organization to their efforts. At the same time Michigan became the home of one of two states to hold a Science Olympiad Competition. The Science and Mathematics Division saw the opportunity to bring the students to Grand Valley through the fun and educational experience of a competition. Thus, the Region 12 Science Olympiad Tournament began.

The success of Science Olympiad led to the Science and Math Update Seminar, a regional professional development mini-conference for science and mathematics teachers that emphasized dialogue and sharing among K-16 educators. The mini-conference attracted educators from all grade levels and surrounding school districts and colleges. It was clear that there was an energetic and enthusiastic group of science and mathematics teachers in Kent, Ottawa, and Muskegon counties.

In 1987, Grand Valley developed and housed the Coalition for Excellence in Science and Mathematics Education. The Coalition functioned to coordinate the efforts of science and mathematics educators in the region and connected the K-16 community to businesses and informal science groups, such as museums, and zoos, interested in supporting STEM education. The major vehicle for communication was the *InterChange*, a monthly newsletter, which still is published, although it is now a virtual one.

In the above photos, area educators, community members, and GVSU faculty and staff enjoyed celebrating at the 25th Anniversary Open House in September.

With Grand Valley's strong commitment to outreach activities in science and mathematics and professors who generously gave of their time and expertise to interact with K-12 students and teachers, the Grand Valley State University Science and Math Center was established in the 1990- 91 academic year. The Grand Valley Science and Math Center continued to sponsor the Science Olympiad, Update Seminars, professional development workshops for teachers, and science programs for students.

Around the same time the State of Michigan began to fund regional mathematics and science centers around the state to promote high quality science and mathematics instruction through leadership, professional development, student programs, curriculum development, and resource development. In 1988, twenty centers had been established and funded by the Michigan State Legislature. However, there were no centers servicing West Michigan. In 1994, funding was provided for a center at Grand Valley State University. It was decided to merge the efforts of the Coalition for Excellence in Science and Mathematics Education and the Grand Valley State University Science and Math Center into the Regional Math and Science Center.

The Regional Math and Science Center is celebrating its 25th Anniversary as a center at Grand Valley beginning with its debut in 1990-91. The Center continues to host the Science Olympiad Tournament, Science Update Seminar, and *InterChange*, in addition to many new programs such as Super Science Saturday, G3 Camp for grandparents and grandkids, Discovering STEM Kits and PRIME Mathematics.

A variety of events will take place to commemorate this exciting event.

InterChange Newsletter

West Michigan Coaches Science Olympiad are invited to Grand Haven High School on Saturday, November 8 for a Coaches Clinic!

You will have an opportunity to attend information sessions stressing how to coach and prepare for the 2015 events. Presenters will be drawn from veteran coaches and event supervisors.

Deadline for registration is October 25, 2014.

Information and registration form.

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Get Ready For Math In Action!

Math in Action Strategies for Student Success will be held February 21, 2015 at Grand Valley State University's Mackinac Hall in Allendale, Michigan!

Math in Action presents lively and informative discussions of current issues in issues in mathematics education while providing an opportunity for practicing PreK – 12 teachers, prospective teachers, curriculum directors, and college and university faculty to share ideas, concerns, and resources. SCECH credits are available for most sessions. The conference consists of six hour-long sessions with eight separate interactive presentations during each. Keynoter, Valerie Mills, will address *Using Item Types that Help in Assessing for Understanding*. Presentations are focused on specific mathematics topics at a variety of grade levels. *The Common Core State Standards for Mathematics* and the *Standards for Mathematical Practice* play a large part in sessions for the 2015 conference.

Look for sessions addressing the teaching of important concepts in mathematics, such as:

- Number and operations
- Fractions, measurement
- Geometry
- Algebra
- Probability, and statistics

Also look for several sessions addressing pedagogical issues such as:

- Common Core State Standards and Standards for Mathematical Practice
- Assessment
- Promoting conversations about mathematics
- Inquiry-based learning
- Engaging students in complex tasks and experiments
- The nature of proof
- Using technology to teach mathematics
- Peer mentoring
- Cooperative learning
- Teaching through games
- Integrating ELA, Math, and Science
- Mitigating summer learning loss
- Engaging families in their children's mathematical education

Participants will have the opportunity to win a classroom set of one of the MCTM *Adventures with Mathematics* games for the grade of their choice. All 13 *Adventures with Mathematics* books will be available for sale (cash or check only) at the conference price of $10 each. Proceeds benefit the MCTM Scholarship Endowment Fund.

For more information about the conference go to the website. The program will be available online in early December 2014. **Submit a proposal** to speak at Math in Action. Proposals must be submitted by Friday, October 3, 2014.

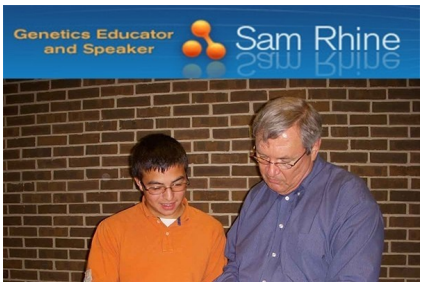
Take Part in Earth Science Week 2014!

Held October 12-18, Earth Science Week (ESW) 2014 will promote awareness of the dynamic interactions of the planet's natural and human systems. "Earth's Connected Systems," the theme of ESW 2014, engages young people and others in exploring the ways that geoscience illuminates natural change processes. By deepening our understanding of interactions of Earth systems -- geosphere, hydrosphere, atmosphere, and biosphere -- Earth science helps us manage our greatest challenges and make the most of vital opportunities.

Resources for teachers may be found here. The Earth Science Week 2014 Toolkit can be ordered here.

Additionally, **October 18 is National Fossil Day** and Michigan Earth Science Teachers Association (MESTA) is hosting events at the Michigan State University Museum. See this issue for details.

Genetic Update Conference for High School Students Coming in November!



Join us this year as Dr. Sam Rhine presents his annual Genetic Update Conference at: Grand Valley State University on Monday, November 10th, 2014

2014-15 Conference Topics:

I. Basic Concepts in Human Cancer:

1. Mitosis - programmed cell birth (symmetric & asymmetric) and Apoptosis - programmed cell death
2. All human cancer originates from a single somatic cell - that acquires some type of DNA damage
3. All cancer is Genetic.....BUT most cancer is NOT Inherited
4. How tumors form - multiple mutations over 20-30 years - lead to invasive, life threatening tumors
5. Tumor Heterogeneity - all tumors are very complex mixtures with multiple clones of mutated cells

II. Cancer Stem Cells - Cancer Cells with "Stemness"

1. Ability to Self Renew and Differentiate - often migratory and resistant to chemotherapy/radiation
2. Some human leukemia can be 'cured' with an antibody molecule vs. CD47 cancer cell marker

III. Human Tissue Engineering - producing human tissues and organs in the laboratory

1. National 'Waiting Lists' for Organ Donations and sources of transplantable body parts
2. Man Made: skin, nose, urinary bladder, ear, artery, cornea, liver, lung, kidney and heart
3. Liver in vitro via liver cell jet printer / Decellularization & Redecellularization for organ production
4. Encapsulated cell therapy for Type 1 Diabetes
5. Producing hearts with iPS stem cells in mammalian chimeric embryos

Each school must pre-register online to attend the conference. Schools that pre-register will receive an updated set of conference notes the week before the conference. Only those who are pre-registered will be able to receive information regarding time changes, delays, postponements, cancellations etc. Please pre-register online at www.samrhine.com

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For conference details & pre-registration go to: www.samrhine.com and click on 'Schedule'. Dr. Rhine says "Feedback evaluation data indicates numerous secondary students are making career decisions almost every day during these programs."

This program is sponsored by the Regional Math and Science Center at Grand Valley State University. Please pre-register with Sam Rhine for parking and event location information at GVSU.

Celebrate the International Year of Light 2015 with Super Science Saturday!

WHAT:

In celebration of the International Year of Light 2015 and the Regional Math and Science Center's (RMSC) 25th Anniversary, the RMSC and the Physics Department at GVSU will be hosting *Super Science Saturday: The Wonder of Light,* a science extravaganza for the West Michigan community. This event will provide educational activities and opportunities for students and their families to experience light as it applies to biology, Earth science, physics, engineering, technology, history, art, and more! The program will focus on understanding the importance of light in our lives and our future. These experiences will include:

- Large group demonstration by GVSU science faculty and/or guest presenters
- Hands-on activities in laboratories and/or classrooms provided by GVSU science, mathematics, engineering, history, geography, and arts faculty, professors from other colleges and universities in our region, pre-service teachers, community science-related organizations, and area business/industry
- Invited guest speakers
- Free-standing and poster displays

WHEN:

Saturday, January 24, 2015 / 10:00 a.m – 4:00 p.m.

WHO:

- K-12 students, teachers, and parents in Allegan, Kent, Montcalm, Muskegon, Newaygo, Ottawa, and VanBuren counties
- GVSU faculty, students, and alumni
- West Michigan community-at-large

WHERE:

Grand Valley State University, Allendale Campus: Seymour and Esther Padnos Hall of Science

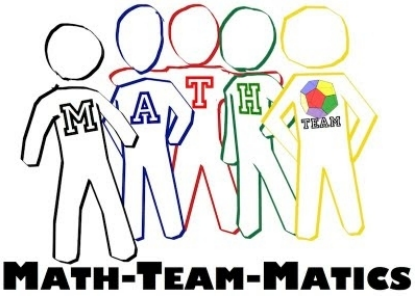
HOW TO BE INVOLVED:

If you are interested in attending, please show up on January 24th, 2015 and be ready for a fun filled day of science! No registration is necessary and the event is completely **FREE**!

If you are interested in presenting or volunteering please contact Chelsea Ridge at ridgec@gvsu.edu.

For sponsorship and promotional opportunities, funds are being accepted here. Additional funds are being provided by the Grand Valley State University Provost's Office, Center for Scholarly and Creative Excellence, College of Liberal Arts & Sciences, Physics Department, and the Regional Math and Science Center.

Register Now for the Second Annual Math-Team-Matics Competition!



This fun and friendly competition will feature creative and engaging problems to bring the mathematical practices to life. The event is hosted by Grand Valley State University's Department of Mathematics and the Regional Math and Science Center on the Allendale Campus.

When: Saturday, November 8th, 2014

Time: 9 a.m.-3 p.m.

Location: Mackinac Hall, GVSU Allendale Campus

Cost: $65.00 for a team of 5 and 1 coach. $8 for each additional lunch.

Registration Deadline: October 24th, 2014

Audience: The event is open to teams of 5 students in 7th-10th grade. There will be a division of 7th -8th graders and division of 9th -10th graders.

This is the only math competition in West Michigan that is open to middle schools! Content for the competition will be drawn from K-8 mathematics as well as high school algebra and high school geometry. The competition will begin with individual and team competitions followed by intense head-to-head "Quiz Bowl"-style team competitions in the afternoon immediately followed by awards. Lunch is provided for students and coaches. Friends and family are welcome to observe the afternoon activities.

Check out our website for example competition questions and additional information or contact Chelsea Ridge, ridgec@gvsu.edu. To register go to our registration page.

Join the Michigan Alliance For Environmental and Outdoor Education Conference!

STREAMING THROUGH ENVIRONMENTAL AND OUTDOOR EDUCATION

Join educators from throughout the state for the October 10-12, 2014 Michigan Alliance For Environmental and Outdoor Education (MAEOE) Conference.

This year's conference will be held at Higgins Lake at the Ralph A. MacMullan (RAM) Conference Center in Roscommon, MI.

We will explore the lakeshore, woods and new classrooms, WHILE connecting standards and ourselves to the outdoors.

Spend your nights in the camp□like lodges or camp right next door, within walking distance, at North Higgins Lake State Park. Booking your room at the RAM Center will be done through your conference registration, as will meals, but campsites or your choice of hotel room will be booked on your own.

Read through the Conference Pre-Program at www.maeoe.com to find out about sessions, our keynote, the Friday night Share-a-Thon, the book store, the silent auction and to make your registration, lodging, meal, field trip and workshop choices before registering. Keep a running total of the fees for your choices—so you can enter it into PayPal at the end of registration.

If you'd like to support the conference with a sponsorship, or come as a vendor or exhibitor—find those forms at www.maeoe.com too!

After you've read through and made your choices from the Conference Pre-Program visit Wild Apricot to register.

Also-if you are not a member-or need to renew-do that before registering by clicking on the Become a Member link on the upper left home page of Wild Apricot.

Visit Fossil Day at the Michigan State University Museum

SATURDAY, OCTOBER 18, 2014

SPONSORED BY MICHIGAN EARTH SCIENCE TEACHERS ASSOCIATION (MESTA)

10 a.m. - Noon

Teacher Workshops

*Pre-registration required, $20 includes box lunch, fossil kit, and other resources Registration for teacher workshops opens 9/19/14 at: www.mestarocks.org

Elementary and secondary levels

Topics include: use of fossils to address NGSS; constructing geologic history from fossil evidence; fossil identification helpful for Science Olympiad

12:30 – 4 p.m.

Family Fossil Fun **FREE Public Event**

Michigan fossil dig & sift

Scavenger hunt

Fossil molds and models to make and take

Face painting

iPad fossil trivia contest – with prizes!

Michigan Geological Survey/CoreKids Program – examine core samples containing fossils

Guided tours of Evolution Hall

"Ask the Expert": a paleontologist will be on hand to answer your fossil questions and to identify specimens

1-4 p.m.

Special opportunity for educators: A "fossils only" version of MESTA's famous Rock Shop will be set up for educators to acquire.

For more information: (517) 432-1472 or msum.education@gmail.com.

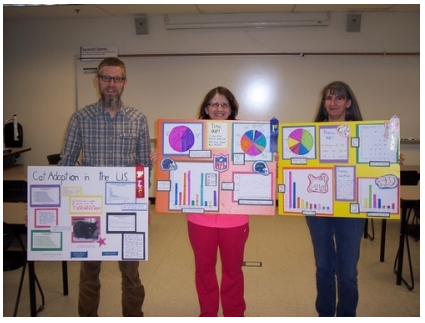
The museum is located at 409 W. Circle Drive, East Lansing, MI 48824

2015 Statistics Poster Competition for K-12

The Department of Statistics at Grand Valley State University (GVSU), the Regional Math and Science Center at GVSU, and the Michigan Council of Teachers of Mathematics are pleased to announce the 2015 Michigan Statistics Poster Competition for K-12.

The *NCTM Standards for Curriculum and Evaluation in School Mathematics* presents the vision that problem solving is a primary goal of mathematics instruction and recommends student involvement in statistical activities at all grade levels. According to the *Standards,* and echoed by the *Grade Level Content Expectations* for Michigan students, statistical thinking should begin in the primary grades with the creation of student data from class activities. In upper grades, collecting, organizing, summarizing, and interpreting data are emphasized. The statistical poster competition is a powerful tool for attaining these goals while exercising essential communication skills. In addition, the competition provides a means for students to be creative and to have fun.

A statistics poster tells the story of a data set through numbers and graphs. A series of four articles that explain the process used to create a statistics poster and photos of last year's winning entries are available at the MSPC website at *http://www.gvsu.edu/stat/statposter*. **All students in K through 12 residing in Michigan are eligible to submit statistics posters to the competition.**



Entries will be judged in four different grade level categories: K-3, 4-6, 7-9, and 10-12. Students may work individually or in teams. For the K-3 category, there is no restriction on the size of the team; it may be as large as the entire class. For the other three categories, the team may have up to four students.

There is no entry fee. The deadline for submitting a poster to the Department of Statistics at GVSU is March 6, 2015 and prize winners will be notified by April 4, 2015. First, second, and third place prizes in the amounts of $72, $48, and $36, respectively, will be awarded in each of the grade level categories, and winning entrants' schools will receive plaques signifying the honor. Honorable mention certificates will be awarded, as well. All posters become the property of the Department of Statistics at GVSU.

Online Registration. Posters can (and should) be registered through the competition website.

For more information, contact event organizer Dan Frobish at (616) 331-3028 or email frobishd@gvsu.edu.

Connections for the STEM Classroom

TIMING IS EVERYTHING: INSIGHTS FROM SIZE-DEPENDENT CHANGES IN ORGANISMAL FORM

Gary K. Greer, Associate Professor, Biology Department, Grand Valley State University

It is a long-standing tradition to begin an essay, particularly one regarding a scientific topic, with a quote – *relevant by inference* - from philosophy, literature, the arts, or Yogi Berra, that confers a courtier-like intellectual status or (as in my case) the veneer of it to the author. Far be it from me to break with the wisdom of Tevye the milkman (and fiddler with a penchant for roofs).

"Observe due measure, for right timing is in all things the most important factor." - Hesiod

To my knowledge all ant species have castes, anatomically differing individuals that serve different roles in the colony. Some are workers that tend the queen and her eggs and larvae, others maintain the integrity of the nest or collect food, and there are soldiers that defend the nest. Anatomical differences among castes may be subtle or drastic, but, they are almost invariantly associated with their relative sizes. For example, soldiers are typically much larger than other castes and possess larger head-to-body and "skull"-to-jaw ratios (Figure 1). They are more than simply larger versions of the smaller castes, they are designed to deliver a bite that is a multiple of their increased size. Similarly, the depth of the skull of the great Cretaceous predator *Tyrannosaurus rex* increased as it developed from a rather tiny hatchling to a nearly seven-ton adult (Figure 2), a change that facilitated the development of large jaw muscles and a truly monstrous bite force (almost 13,000 pounds or 3.5 times that of an Australian crocodile [1]). *Ouch!*

Figure 1. Pogonomyrmex badius, the Florida harvester ant by Alexander Wild; permissions@visualsunlimited.com.

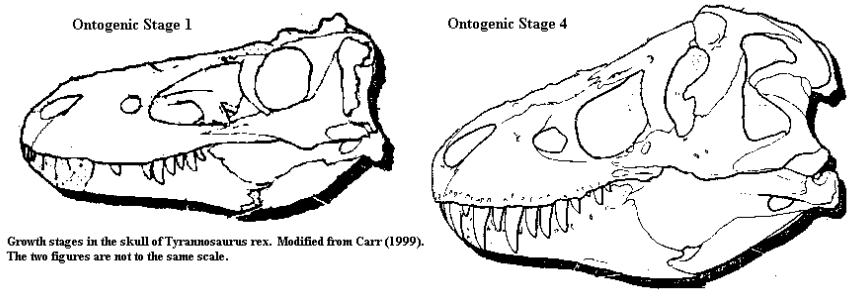


Figure 2. Change in skull morphology in Tyrannosaurus rex from juvenile (left) to adult (right); not at same scale. Permission via Palaeos.com.

Allometry is the study of size-dependent changes in form (allo- “different” and metry – “measurement”) such as those described above. Three terms relating to allometry are very useful. A trait that increases at the same tempo as total body size is said to be isometric (i.e., “same measurement”). Head size in most worker ants grows at the same pace as the entire body, resulting in an isometric head-to-body ratio throughout life. In contrast, a trait that increases faster than total body size is said to be *positively* allometric. Head size in soldier ants is such a trait. Conversely, traits that increase at a slower rate than the overall size of an organism are said to be *negatively* allometric. A head-to-body example of negative allometry can be observed in humans, wherein our heads grow at a slower rate than our bodies as we mature from infant to adult (Figure 3). Most animals and plants possess a number of traits that are allometric, some of which may be positively allometric while others negatively so in the same organism. My aim in this essay is to provide a few examples of the considerable insights in ecology, evolution, and medicine that can be gained from the study of allometry.

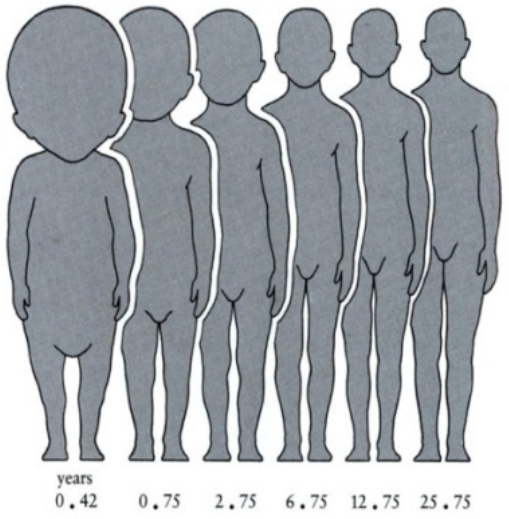


Figure 3. Change in head-to-body ratio in humans from birth to reproductive maturity; with permission from the Journal of Vertebrate Paleontology.

Let me show you a few examples of allometry that provide important ecological insight, beginning with changes in the body of the flying squid (*Todarodes pacificus; aka* Japanese common squid). The flying squid’s body width is negatively allometric resulting in a change from a rounded juvenile form to a streamlined adult form[2] (Figure 4). Conversely, the length and width of the fins on the mantle are positively allometric, creating proportionally increasing steering planes that optimize the squid’s ability to swim backwards with great speed and even take flight – up to 100 feet. These body and fin changes are also associated with a switch in prey from primarily crustaceans (e.g., shrimp) to fish, minimizing competition for food among juvenile and adult flying squid [2].

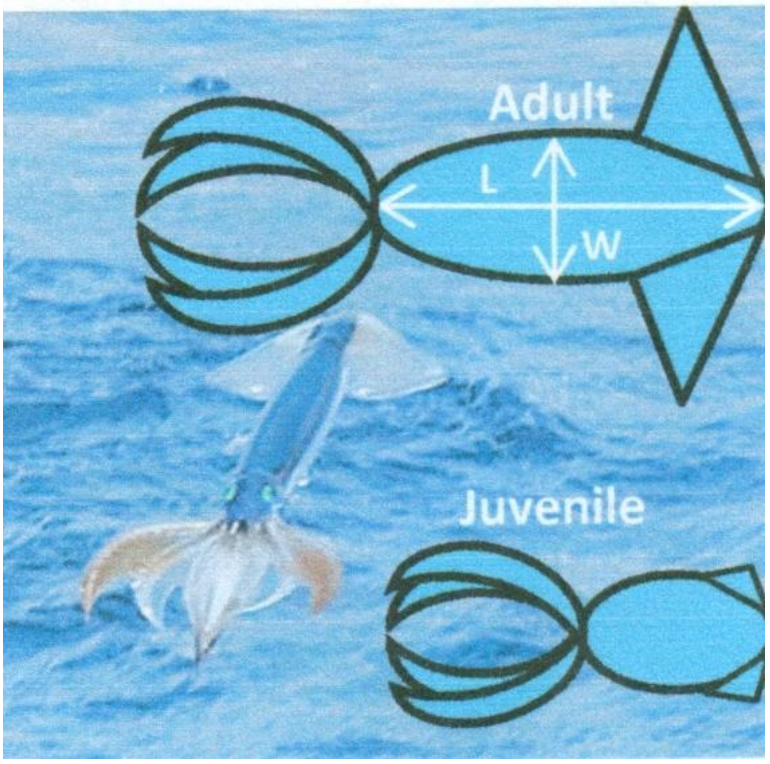


Figure 4. Flying squid. Photo by Graham Ekins; permission via Flickr-The Commons.com. Idealized juvenile and adult body dimensions superimposed; L = length, W = width.

The allometry of a trait may be fairly rigid as is the case for flying squid body and fin dimensions, however, the allometry of other traits is sensitive to the environment, shifting to optimize survival and reproduction. This flexibility is technically known as adaptive (trait) plasticity. The early life of tadpoles provides a prime example that can be observed here in Michigan or easily replicated using experimental aquaria. Tadpoles that develop in ponds with high densities of diving beetle larvae possess high-profile tails conferring greater strength for escaping the clutches of these strong ambush predators. In contrast, tadpoles that develop in the presence of bluegills possess sleek, low-profile tails that confer the speed needed to escape these pursuit predators (Figure 5)[3].

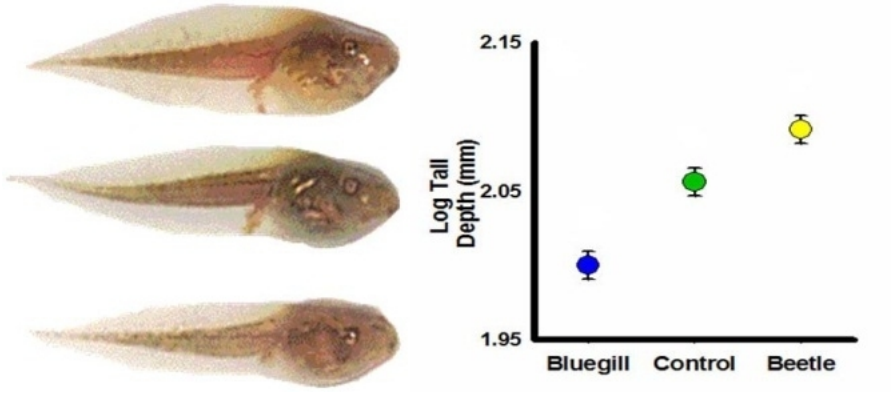


Figure 5. Tadpole tail depth in response to the presence of diving beetle larvae and bluegills. Image used by permission from Michael Benard's Pacific Chorus Frog website.

Plants are the masters of adaptive plasticity because allometry and plasticity are aspects of developmental processes and plants are composed of repeating shoot (stem + leaf) and root modules, each being born, developing and dying semi-autonomously. The primary appendage of a plant is the leaf and many plant species exhibit changes in the size and shape of their leaves as the plant gets larger. For example, tree ferns and white oaks produce increasingly large leaves as the tree increases in size with the obvious benefit of increased light capture. The successively larger leaves also become increasingly complex (i.e., lobed or dissected) such that the leaflets eventually have their own (sub)-leaflets which themselves become increasingly dissected (both positively allometric; Figure 6).

Figure 6. The twenty inch-long frond of a juvenile tree fern (top) and the eight foot-long frond of the tree-fern Cyathea aborea. Photos by G. Greer.

Similarly, the lobes of white oak leaves become deeper as one travels from base to uppermost-tip of the tree's canopy (another positive allometry). The higher a leaf is located on a tree, the greater its distance from source of water (the soil) and the greater its exposure to heat and wind, which strip it of its water. The leaves at the top of an oak tree are the first to lose their water supply when the soil becomes dry and simultaneously the most vulnerable to water loss. The deep lobbing of these leaves minimizes the distance from a water-conducting vein (xylem) to water-demanding photosynthetic tissues and also minimizes the distance between these heat absorbing tissues and the leaf edge where heat is released[4]. Similar advantages are associated with plants that are partially submerged (e.g., *Ranunculus aquatilis*), where leaves that develop underwater will be deeply dissected, facilitating gas exchange, particularly absorption of carbon dioxide[4]. Leaves that develop above water will be fully "webbed" where carbon dioxide is easily acquired (Figure 7).

Figure 7. Illustration of Ranunculus aquatilis L., excerpted from Watson, L., and Dallwitz, M.J. 1992. The families of flowering plants: descriptions, illustrations, identification, and information retrieval. Version: 22nd July 2014. http://delta-intkey.com'.

The study of allometry also reveals key differences in major groups of organisms – in this case plants - and hence key differences in their ecological roles in the world today. A minimum size is required for reproduction, particularly among perennials. Investment into reproduction above this size-minimum is positively allometric and often adaptively plastic. For example, once a Christmas fern (*Polystichum acrostichoides*) reaches the minimum size required for reproduction, its investment into reproduction increases or decreases with its growth rate, which is an outcome of the quality of the environment[5] (Figure 8).

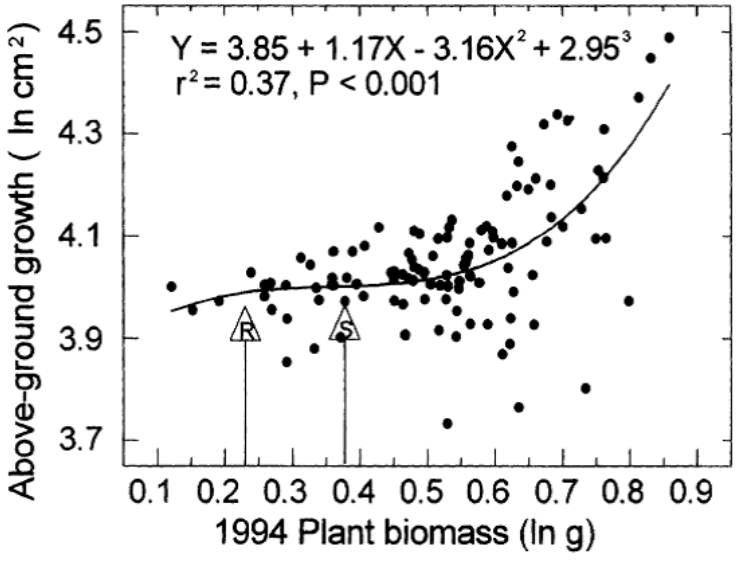


Figure 8. Reproductive allometry of the Christmas fern, Polystichum acrostichoides. The arrow with an 'R' indicates the average minimum size necessary for reproduction and the arrow with an 'S" indicates the size necessary for sequential (year-to-year) reproduction as a function of growth rate. From Greer and McCarthy, 1997, Patterns of Growth and Reproduction in the Christmas fern, Polystichum acrostichoides. American Fern Journal 90:60-76.

This “cautious” strategy maximizes the lifespan of the fern by minimizing the impact reproduction has on parent-plant survival. Because offspring survival is extremely low in ferns, this “cautious” strategy maximizes *lifetime* reproductive success (i.e., production of offspring that survive to adulthood) by giving an adult fern the maximum possible opportunities for reproduction. Not surprisingly, many fern species are very long-lived, from many decades to centuries. The opposite pattern occurs in many flowering plants. Species in the genus *Pedicularis*, a relative of snapdragons, invest more into reproduction at smaller sizes in stressful, high elevation environments where growth rate is slower than in favorable, low elevation environments where growth rate is higher[6] (Figure 9). A very similar trend was observed by my 2012 Plant Ecology class of subpopulations of the smooth aster, *Symphotrichum laeve*, occurring at the droughty top versus the wetter, growth-favorable bottom of the old ski hill at GVSU’s Allendale campus (Figure 10). These positively-allometric shifts in reproduction in stressful, low growth, environments increase the likelihood of reproducing before death. The contrasting allometric responses by ferns and flowering plants reflects key differences in their physiology and reproduction. The comparatively low rates of resource acquisition and spore survival in ferns favors a strategy that maximizes survival of adult plants whereas the comparatively high rates of resource acquisition and seed dormancy in flowering plants, favor a strategy that maximizes reproductive output; exceptions not-withstanding.

Figure 9. Pedicularis kansuensis. Photo from 'eFloras (2008). Published on the Internet http://www.efloras.org [accessed 7 April 2008] Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA.

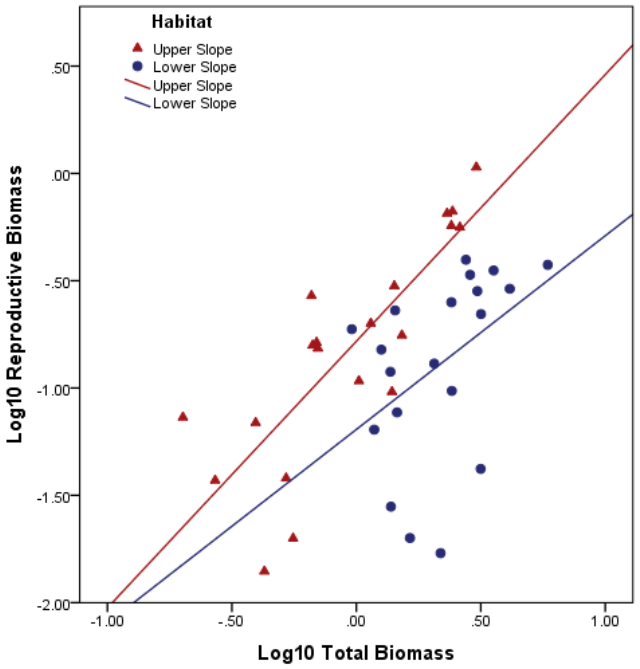


Figure 10. Reproductive allometries for sub-populations of Symphotrichum laeve occurring on the upper-slope (red line) and lower-slope (blue line) of GVSU's old ski run.

A considerable amount of macroevolutionary change in plants and animals (i.e., profound changes in form, anatomy, and physiology that typically manifest over a great number of generations) can be viewed as products of allometry. This macroevolutionary aspect of allometry is technically referred to as heterochrony (hetero = different, chrony = time); i.e., the speeding up or slowing down of development of different body parts between ancestors and descendants. Two notable examples of heterochronic evolution in plants include: (1) the evolution of lobed and dissected leaves[4] (*a very complicated tale that I confess to simplifying here, but, nonetheless true to the point*), and (2) the very rapid evolution of single-stalked, soft kernelled maize (corn, *Zea mays* subsp. *mays*) from its still living, multi-stalked, hard kernelled, Central American ancestor, teosinte (*Zea mays* subsp. *Parviglumis*)[7]. Among animals, notable examples of heterochronic evolution include the increasing skull-height-to-skull-length ratio that followed increasing size in tyrannosaurids, a cross-generational (and cross-species) reflection of the positive allometry individuals experienced from juvenile to adult described above[1]. Tyrannosaurid skull evolution simply followed along and exaggerated a pre-existing allometry. Another example from animals is that of the modern horse hoof from a five-toed ancestor, wherein all toes but the center toe suffered a deceleration (i.e., negative allometry) compared to the limbs, while the center toe experienced an acceleration (i.e., positive allometry) that correlated with similar acceleration of the limb bones[8]. This complex set of macroevolutionary changes facilitated the evolution of increasing running speed, an adaptation for avoiding predation in grasslands, the new and rapidly expanding biome of the Eocene and Miocene[9,10]. Similarly, the independent loss of limbs in apodans (a group of amphibians), snakes (a group of reptiles), and whales (a group of mammals) were outcomes of heterochronic slowing (i.e., negative allometry) relative to body growth. We can also see the products of heterochronic evolution in ourselves. As I described above, the head-to-body ratio in humans decreases as we mature from fetus to adult, the product of a negative allometry of our head growth relative to our bodies (Figure 3). Nevertheless, development of our cranium – *and brains within* – expands at a faster rate than the rest of our skull, a positive allometry with a steeper slope than for any other primate[11] (Figure 11). As a result, we humans possess exceptionally large brain-to-body size (weight) ratios, an important factor in the evolution of our high level of socio-technological intelligence that followed an initial reorganization of the brain in our early hominid ancestors[11]. The evolution of this remarkable trait, our brainy heads, the engine of our intelligence, creativity, and technical abilities, is the product of a positive heterochrony, that is, a cross-generational positive allometry.

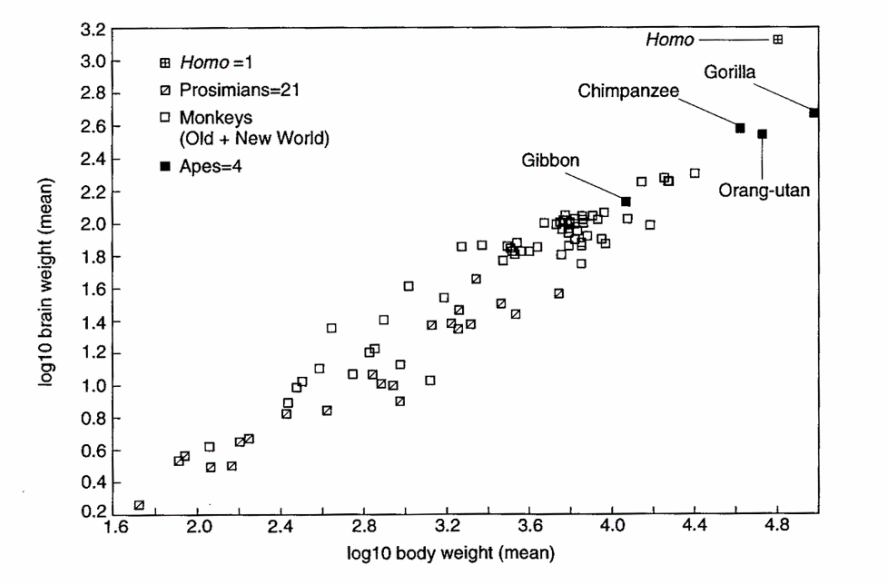


Figure 11. Brain weight plotted against body weight for primates; both plotted in log_{10} scale. Figure from Holloway et al 2003.

Allometry has medicinal utility as well. A common attribute of many cancers is that the likelihood of metastasis (the spread of cancerous cells from its original site to another) increases much more rapidly than tumor size when tumors are small, that is, the likelihood of metastasis is positively allometric at small sizes (Figure 12). The likelihood of metastasis levels off with larger tumor sizes, indicating a negative allometry. In the case of the breast cancer study by Demicheli et al. (2006)[12], a critical tumor size at which the likelihood of metastasis appears to switch from a positive to a negative allometry appears to be around 10,000mm^3. When it comes to metastasis, small tumors are more dangerous than large tumors. This insight clarifies the importance of early detection of cancers and careful monitoring following removal of cancerous tumors.

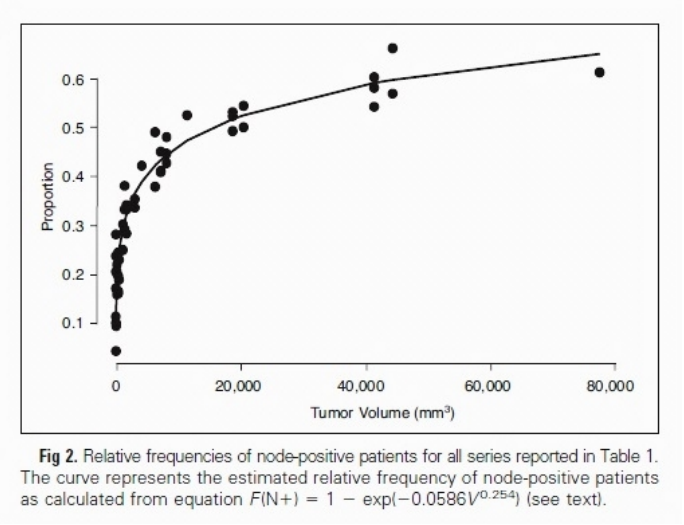


Fig 2. Relative frequencies of node-positive patients for all series reported in Table 1. The curve represents the estimated relative frequency of node-positive patients as calculated from equation $F(N+) = 1 - \exp(-0.0586V^{0.254})$ (see text).

Figure 12. Proportion of patients with lymph-nodes containing cancer cells based on the size (volume) of a patient's initial tumor. From, Romano Demicheli, Elia Biganzoli, Patrizia Boracchi, Marco Greco, William J.M. Hrushesky, Michael W. Retsky. 2006. Allometric Scaling Law Questions the Traditional Mechanical Model for Axillary Lymph Node Involvement in Breast Cancer. Journal of Clinical Oncology, Vol 24: 4391-4396.

The underlying genetic basis of allometry is far beyond the scope of this essay, but, not surprisingly, it depends on the specific organism and the specific trait(s) concerned. In some cases just a few genes that orchestrate the activities of other genes and subsequently a number of "linked" traits appear to be involved. For example, the rapid evolution of the single-stalked form and soft kernels in maize from its ancestor teosinte, which is multi-stalked and possesses hard kernels, is the product of just a few regulatory genes, perhaps as few as two[7]. In other cases – as with leaves and their lobing and dissection – the underlying genetic mechanisms are complex, a cascading gene network characterized by numerous stimulating and

repressing feedbacks (i.e., up-regulation and down-regulation of gene activity). In most cases, our understanding of the underlying genetic mechanisms is largely absent with only a few heavily research examples so far, some of which are presented above.

There is much yet to learn regarding allometry to much potential benefit, both in terms of basic and applied knowledge. I hope this is a source of inspiration for students considering a future in biology.

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