|  |  |
| --- | --- |
|  | **A Matter of Human Proportions**  ***Are you Vitruvian?*** |

**Overview**

This project is an opportunity for students to learn:

* How to use the metric system to measure liner distances
* Whether proportions that exist between parts of the human body are consistent across individuals
* How to form a hypothesis, analyze data, and then argue whether evidence supports the hypothesis

|  |  |  |
| --- | --- | --- |
| **Concepts**  Metric System, Anatomical Scaling, Body Proportions, Ratios, Linear Regression  **Skills**  Testing Hypotheses, Metric System Measurement, Creating Scatterplots, Performing Linear Regressions |  | **Module Type:** Lab activity  **Duration:** One 2 hr class session  **Key Materials**   * PowerPoint presentation * Projector * Computers with Excel * Meter sticks, or meter tape |

**Authors**

Vikram Baliga, PhD Candidate, Ecology and Evolutionary Biology UC Santa Cruz

Sarah Baumgart, Health Academy Teacher, Watsonville High School

**Science Education Standards**

**National:** Science in Personal and Social Perspectives; Science As Inquiry; History and Nature of Science

**California:** Investigation and Experimentation; Math – Algebra 1

**Field Tested**   
11th-12th grade Anatomy and Physiology, Watsonville High School, Watsonville, CA (Fall 2012)

**Navigate:** [Background](#Background) [Materials &Time](#Materials) [Starting Point](#StartingPoint) [Procedures](#Details) [Standards](#Standards) [Supplemental](#Supplemental)

# Background for Teachers

**Why this matters:**

Not only does this lab introduce the historical and cultural significance of Leonardo da Vinci’s Vitruvian Man drawing, but it also provides a high-interest way for students to familiarize themselves with the metric system. They then apply their working knowledge of this measurement system to their own bodies. Students explore patterns in human anatomical scaling by taking linear measurements of various body parts. They then use Microsoft Excel to analyze data and determine whether the evidence they gathered supports their hypotheses. The lab only requires metric measuring tools (such as tape measures or meter sticks) and access to computers with Excel. In addition, this activity serves as an excellent icebreaker for students and can promote positive body image, as it focuses on *how* variable trends in human body proportion can be seen across individuals.

**Assumed background:**   
We assume that students already know the following:

* What a scatterplot is
* What a trend line is
* The equation for trend lines (y = mx + b) and what each component of the equation means (i.e., “m” stands for slope, “b” stands for intercept…etc)

We assume that teachers are familiar with Microsoft Excel

**Special context:**This lab draws inspiration from the Vitruvian Man, an illustration created by Leonardo da Vinci that depicts a male figure in two superimposed positions. In each of these positions, the figure has spread his arms and legs apart, and is simultaneously inscribed in both a circle and square. This human figure represents “ideal” human proportions as described by the ancient Roman architect Vitruvius (Walshe 2006, Pastorello 2012). Da Vinci’s drawing remains one of the most referenced and reproduced images in the world, appearing in books, films, and even coins.

**Scaffolding supplements:**

There are a number of supplements that accompany this document:

1. “The Metric System.ppt”: A PowerPoint presentation to introduce the metric system (what it is, who uses it, how to use it)
2. “Metric System Handout”: A PowerPoint presentation of a student handout, to be used during “The Metric System” presentation
3. “Vitruvian Man Student Worksheet.docx”: A student worksheet to use during the Vitruvian Man activity
4. “Class Data Sheet.xlsx”: An Excel spreadsheet that can be used by the teacher in analyzing data from Part I of the activity
5. “Vitruvian Man Stats.pptx”: A PowerPoint presentation to explain the graphing and statistical methods used for data analysis
6. “VM Excel 2003 Instructions.doc” or “VM Excel 2007-2010 Instructions.docx”: A student handout to help outline data analysis in MS Excel.

# Module Description

## Materials:

* Metric rulers
* Metric tape measures
* Computers with Microsoft Excel (2003 or newer)

## Preparation:

We recommend that you remove all Imperial-system (i.e., feet / inches) measurement tools from the classroom before the activity begins. This will help ensure that all measurements are taken in metric units.

To make height measurement easier, we strongly encourage you to tape a long sheet of butcher paper to a wall. Students can then stand against the wall, with shoes removed, and the heights of the marks can be measured with a meter stick or metric ruler.

## Timeline:

1. Introduce/review the metric system (18 min)
2. Introduce the Vitruvian Man drawing / historical context (7 min)
3. Students take measurements (25 min)
4. Go over graphing and statistical methods (20 min)
5. Students analyze data (40 min)
6. Review and cleanup (10 min)

## Starting Point for Inquiry:

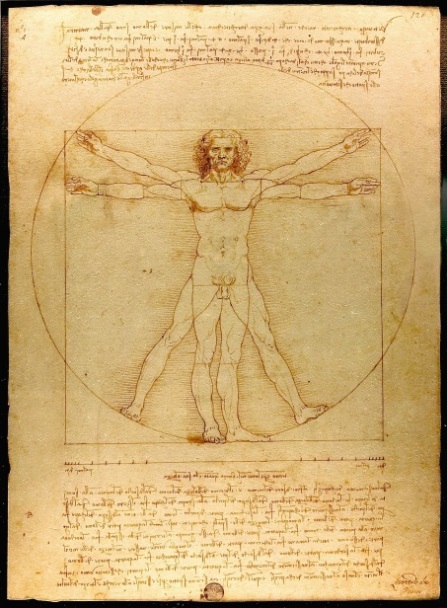
Leonardo da Vinci, a famous Italian renaissance inventor and painter, was greatly influenced by the work of a man named Vitruvius. Vitruvius was a Roman architect who lived during the first century B.C. who created a model of what he thought were ideal proportions for a man (Walshe 2006, Pastorello 2012). In da Vinci’s Vitruvian Man drawing, a human figure represents the proportions described by Vitruvius (Figure 1). Da Vinci’s drawing, which was made in 1490, remains one of the most referenced and reproduced images in the world, appearing in books, films, and even coins (Pastorello 2012).

Figure 1 The original Vitruvian Man drawing, as it appears in one of da Vinci’s notebooks

Although this activity only focuses on two proportions found in the drawing, there are far more provided by da Vinci:

* from the hairline to the bottom of the chin is one-tenth of the height of a man
* from below the chin to the top of the head is one-eighth of the height of a man
* from above the chest to the top of the head is one-sixth of the height of a man
* from above the chest to the hairline is one-seventh of the height of a man.
* the maximum width of the shoulders is a quarter of the height of a man.
* from the breasts to the top of the head is a quarter of the height of a man.
* the distance from the elbow to the tip of the hand is a quarter of the height of a man.
* the distance from the elbow to the armpit is one-eighth of the height of a man.
* the length of the hand is one-tenth of the height of a man.
* the root of the penis is at half the height of a man.
* the foot is one-seventh of the height of a man.
* from below the foot to below the knee is a quarter of the height of a man.
* from below the knee to the root of the penis is a quarter of the height of a man.
* the distances from the below the chin to the nose and the eyebrows and the hairline are equal to the ears and to one-third of the face.

## Detailed Procedure:

Introduce/Review the Metric System

Refer to “The Metric System” PowerPoint presentation, designed to introduce the metric system. This presentation includes what the metric system is, justifications for using it, and a framework for understanding how to use it. It also includes a few practice problems that highlight the relative ease of converting between different units. There is an accompanying student handout entitled “Metric System Handout”, in which students fill in missing units by identifying correct prefixes and base units. The chart is designed to help students understand how to convert between different units.

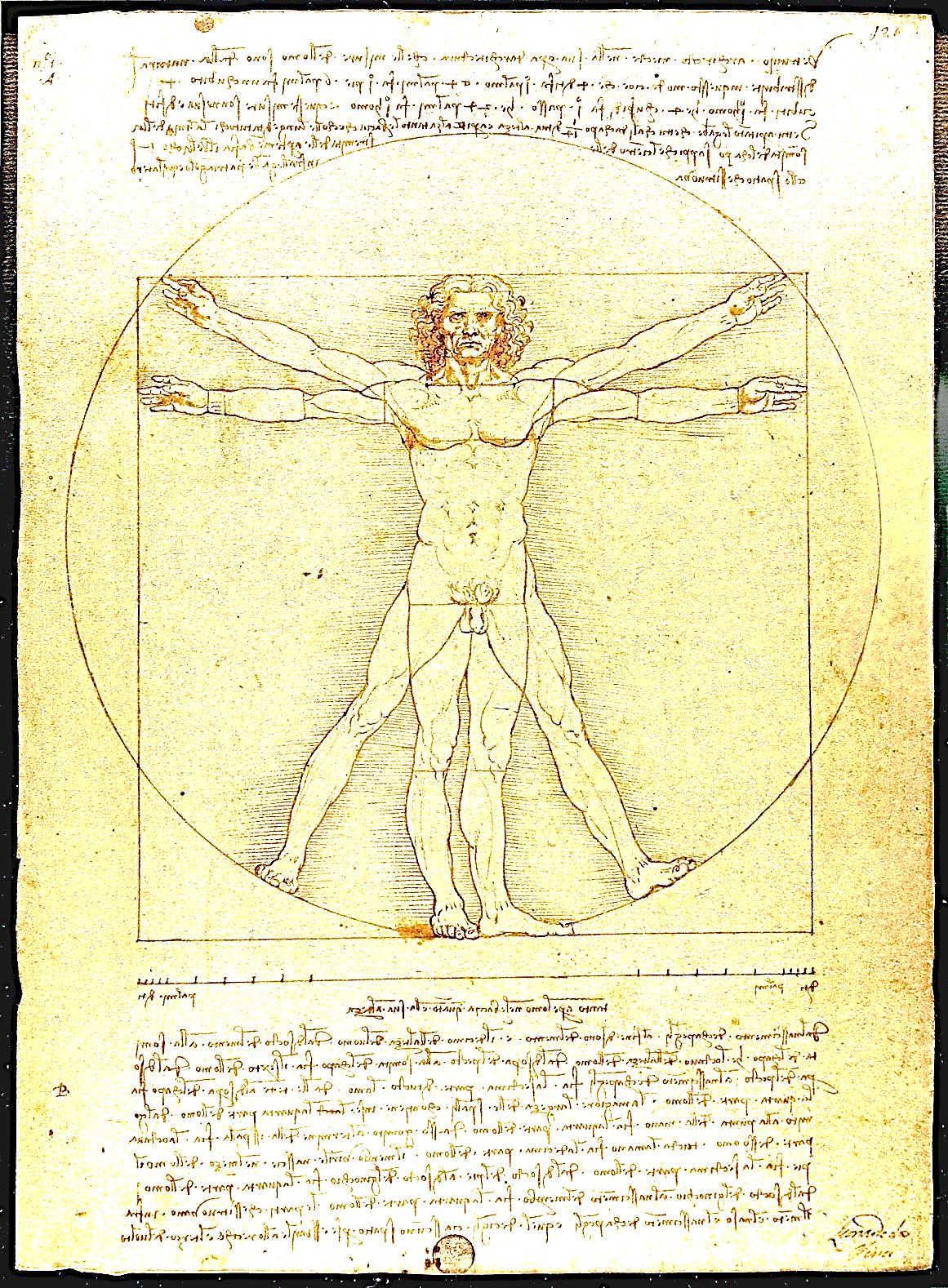
## Introduce the Vitruvian Man

Refer to “Starting Point for Inquiry” section to help introduce the Vitruvian Man drawing by Leonardo da Vinci. Distribute the “Vitruvian Man Student Worksheet” and have students read the “What is the Vitruvian Man?” historical background section. The drawing shows a man standing in a square, as well as inside a circle. The man has two pair of outstretched arms and two pair of outstretched legs. There are many proportions that the body of the Vitruvian Man displays. The two on which we will focus are:

Proportion A: The span of the man’s arms is equal to his height.

Proportion B: The distance from the bottom of his kneecap to the bottom of his foot is one-fourth of his height (while standing).

Please refer to Figure 2 for a diagram of the distances used in these proportions.



Y

Z

X

Figure 2 The linear distances measured in Part 1 of the activity. Distance X indicates arm span, Y indicates height, and Z indicates the distance from the bottom of the kneecap to the bottom of the foot. All measurements should be taken while standing.

Students Take Measurements (Activity Part 1 and Part 2)

Divide the class into small groups (ideally, 4 students per group). Assign each group to one of the two aforementioned proportions. Students will then record their heights and the other measurement they are assigned (span of arms or width of shoulders) in Part 1 of their worksheets. All of these measurements should be made to the nearest 0.1 centimeter. Once students have collected these measurements, they will provide them to you. Record these measurements in a class-wide data sheet (you should have time to do this as students are gathering data for Part 2). We recommend making two separate tables: one for each proportion under investigation. A “Class Data Sheet” Excel file is provided, with separate sheets for each of these tables (see Figure 3, below).



Figure 3 Separate sheets within the Class Data Sheet Excel file, corresponding to the two proportions investigated

## In Part 2 of the Vitruvian Man activity, students will gather data to examine other proportions that might exist in the human body. Here, they have the freedom to examine a few regions of the body to see if scaling patterns are consistent across individuals. It is extremely likely that students will not have a sense of what the proportions might be, so in each case instruct them to not worry about making a hypothesis about the magnitude of the proportion itself. Instead, they will test the hypothesis that the same proportion is found across all people. Thus, the goal is for students to merely examine whether patterns exist by assessing how variable their data is.

## Each group will explore two such patterns. For each case, the group will measure at least 12 individuals from the class to ensure that they have collected enough data to make a reasonable conclusion.

## For the sake of simplicity, we recommend that all measurements be taken as linear distances (in other words, avoiding measurements of surface area or mass). Please refer to the “Possible Pitfalls” section below for further details.

Data Analysis and Conclusions

Part 1

You will demonstrate to the class how scatterplots are created in Excel with all the data your students gathered as a class for Part 1 of this activity. Distribute either “VM Excel 2003 Instructions.doc” or “VM Excel 2007-2010 Instructions.docx”, based on the version of Excel available on your students’ computers. Have the students follow along as you create separate scatterplots for Proportion A and Proportion B. For each of the proportions from Part 1, students’ heights should be assigned to the x-axes of their respective scatterplots. Once each of these scatterplots is created, you will show you how to title and label the axes of each scatterplot. Finally, you will add a (linear) trend line to each scatterplot, choosing to display both the equation for the line and the associated R2 value.

Students will then write down the equations for the trend lines and their R2 values on their worksheets. They will then assess how variable the relationships they observed are by distinguishing whether a strong association is apparent. Often, there will be outliers in the data set, the presence of which will affect both the R2 value and the slope of the trend line. Scientists and statisticians often debate about the best way to deal with outliers. There are a few options: 1) remove the outliers outright, 2) re-measure the values of the outliers, or 3) create two scatterplots (one with the outliers, and one without the outliers) and present both in the final report. The best course of action is context-specific and often requires ethical decisions. This presents an opportunity for you to discuss with your students how they feel about the options of dealing with outliers. Once the class has reached a consensus, the hypotheses can be accepted or rejected.

Students will finally decide whether they accept or reject the hypotheses that these proportions accurately describe the human body. For this activity, we consider getting an R2 value greater than or equal to 0.9 as strong association between the variables. More accurately, investigators would need to run *t*-tests to truly test the significance of the slopes, which requires determination of the standard errors of the slopes. We feel such tests are beyond the scope of this activity.

Be sure that students consider both the slope of the line and the R2 value obtained. If Proportion A accurately describes the body, the slope should be close to 1.0. This is because as height increases from student to student, it is predicted that arm span increases just as much. If Proportion B accurately describes the body, the slope should be close to 0.25 (assuming you placed height on the x-axis). This is because the knee-to-foot length is predicted to always be one-quarter of the total height.

Part 2

Instruct students to follow the instructions on the Excel instructions sheets to enter the data they collected for Part 2 into separate tables in Microsoft Excel. For each table of data, they will create a scatterplot depicting the relationships between the two body regions they measured, and add trend lines to them. Once they have created these scatterplots and labeled them appropriately, they will print them out.

In creating these scatterplots, it may be unclear which variable belongs on which axis. Generally speaking, this may not matter, but if one body region is consistently larger than the other (i.e., leg length is almost always greater than shoulder width), we recommend placing the larger variable on the x-axis.

As in Part 1, students will record the equations for the trendlines and their R2 values on their worksheets and decide whether they accept or reject the hypotheses that these proportions accurately describe the human body.

## Assessment Methods:

## Students who successfully master the content will be able argue why they drew their conclusions in an articulate manner. They will understand why examining both slope and R2 are integral to the process of interpreting data. The slopes acquired provide estimates of the magnitudes of each proportion investigated. The R2 values provide measures of how well the linear trendlines match the data gathered, indicating “goodness of fit”.

Successful students will also know how to accurately label and title scatterplots.

## Possible Pitfalls:

We strongly recommend that students avoid measuring body weight or girth. Doing so may cause some students to feel self-conscious and promote a negative body image. You should instead encourage students to look at this activity as an opportunity to learn more about how their own bodies are composed.

Students often possess a fear of the metric system, due to unfamiliarity. You should stress how important the metric system is to scientific research. As previously stated, we feel you should also remove all Imperial-system measuring tools from the classroom before the activity begins.

Students should take measurements of height or foot/leg lengths with shoes off.

## Glossary:

Correlation – the simultaneous change in value of two numerically-valued random variables.

Leonardo da Vinci – (1452-1519) an Italian Renaissance painter, sculptor, architect, engineer, anatomist, and inventor (among many other things). He was described as the archetype for the ideal “Renaissance Man”, one whose expertise and interests span a significant number of subject areas. Among Leonardo’s most famous works are the Mona Lisa, The Last Supper, and the Vitruvian Man.

Linear – relating to, or resembling a straight line

Linear Regression – an approach to modeling that assumes the relationship between variables is linear

Outlier(s) – value(s) far from most others in a data set

R2, or R-Squared – also known as the Coefficient of Determination, it is the proportion of variability in a data set that is accounted for by the statistical model

Statistical Model – a description of relationships between variables in the form of mathematical equations.

Vitruvius – (80 BCE – 15 BCE) a Roman architect and engineer who considered the human body to be the greatest work of art. His definitions of ideal proportions in the human body later inspired Leonardo da Vinci’s drawing, the Vitruvian Man.

Vitruvian Man – a drawing completely by Leonardo da Vinci circa 1490, which depicts a male figure in two superimposed positions. In each of these positions, the figure has spread his arms and legs apart, and is simultaneously inscribed in both a circle and square. This human figure represents ideal human proportions as described by the ancient Roman architect Vitruvius

## Works Cited:

Pastorello, Thomas. "Leonardo Squared the Circle! -- Da Vinci’s Secret Solution in the Vitruvian Man Decoded."  The About Group, 13 Apr. 2012. Web. 01 Aug. 2012. <http://arthistory.about.com/library/weekly/bl\_leo\_vitruvian\_man.htm>.

Walshe, Roger. "Vitruvius's Theories of Beauty." *Vitruvius's Theories of Beauty*. The British Library, 19 May 2006. Web. 01 Aug. 2012. <http://www.bl.uk/learning/cult/bodies/vitruvius/proportion.html>.

# Science Education Standards Addressed

**Next Generation Science Standards (NGSS):**

Core Idea LS1: From Molecules to Organisms: Structures and Processes

LS1.B: Growth and Development of Organisms

Core Idea LS3: Heredity: Inheritance and Variation of Traits

LS3.B: Variation of Traits

Dimension 2: Crosscutting Concepts

1) Patterns: Observed patterns of forms and events guide organization and classification, they prompt questions about relationships and the factors that influence them.

3) Scale, proportion and quantity: In considering phenomena, it is critical to recognize what is relevant at different measures of size, time and energy and to recognize how changes of scale, proportion, or quantity affect a system’s structure or performance.

4) Systems and system models: defining the system under study -- specifying its boundaries and making explicit a model of that system – provides tools for understanding and testing that are applicable throughout science and engineering.

6) Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

Practices for K-12 Science Classrooms

1. Asking questions (for science) and defining problems (for engineering)

2. Developing and using models

3. Planning and carrying out investigations

4. Analyzing and interpreting data

5. Using mathematics and computational thinking

6. Constructing explanations (for science) and designing solutions (for engineering)

7. Engaging in argument from evidence

8. Obtaining, evaluating, and communicating information

**National Science Standards (NSES)**

A. Science As Inquiry (p.175-176)

E. Science and Technology (p.192-193)

G. History and Nature of Science (p. 200-204)

**California Public Schools Standards (SCSCPS)**

Investigation and Experimentation, 1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing content in the other four strands, students should develop their own questions and perform investigations. Students will:

**a**. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

**c**. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.

**d.** Formulate explanations by using logic and evidence.

**Other California Education Standards**

Math - Algebra I

16.0 Students understand the concepts of a relation and a function, determine

whether a given relation defines a function, and give pertinent information about

given relations and functions.

NSES (<http://www.nap.edu/catalog/4962.html>)

SCSCPS (<http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf>);