I'm not a bot

Stomata control the movement of gases in and out of a leaf, making carbon dioxide available for photosynthesis, and controlling the loss of water from the leaf through transpiration. Stomatal density varies between monocots and dicots, between plant species, and between the underside and top side of the leaves on a plant. There are a number of ways to measure stomatal density, and the different techniques are explored here. One popular method has been to use clear nail varnish to make an impression of the epidermis. Other methods include using Germolene New Skin and using a water-based varnish from DIY shops. We also suggest some potential investigations for students to carry out. Because of the size of stomata, you will need a reasonably good microscope for this. Your choice of magnification will depend on the leaf material that you are using, and the size of the stomata. Image showing stomata under the lens of a mircroscope by John Adds. The image shows a surface view of the lower epidermis of Kalanchoe (Kalanchoe sp.), a dicotyledonous plant. Three stomata and their associated guard cells are shown. Each pore or stoma is surrounded by two sausage-shaped guard cells, which change shape to control the size of the stomatal aperture. In the majority of leaves with an upper and lower surface (dorsiventral) like this dicot, most stomata occur in the lower epidermis. They are usually evenly distributed in the leaves of monocots. The stomata of most species open in daylight and close in the dark. Those plants that use CAM photosynthesis (an adaptation to reduce water loss in arid conditions), stomata close during the heat of the day, to reduce evapotranspiration, and open at night to absorb carbon dioxide for use in photosynthesis. The guard cells contain chloroplasts (visible in this image), but in most plant species they are not able to carry out the full process of photosynthesis. The wavy blue lines, looking rather like a jigsaw puzzle, are the cell walls of the epidermal cells. Guard cells develop and differentiate from epidermal cells. Update your subject knowledge Update your own knowledge of stomata in under 5 minutes, with two short videos from one of the UK's leading biologists. In this 3 minute video, Prof Alistair Hetherington introduces 'The Mystery of the Evolution of Stomata'. In this 4 minute video, Alistair explains why fundamental research, such as his own on stomata, helps us respond to climate change. These videos would also be suitable for post-16 biology students. Selecting your plants One of the best plants for doing epidermal peels is the red hot poker plant Kniphofia. Being a monocot its stomata are highly ordered in rows, but they are big and great for stomatal opening and closing using solutions of different concentrations. Almost as good is the Elephants Ear Saxifrage Bergenia. This also peels very easily, but the stomata are smaller although clearly visible at x100 magnification. This is a dicot so the distribution is more random. Geraniums (a dicot) and spider plants (another monocot) also make excellent stomatal peels. Using Clear Nail Varnish Using clear nail varnish is a traditional method to measure stomatal density, since making the impression and viewing it under a microscope can be completed in one lesson. However, some leaves are prone to damage from the solvent in the nail varnish. The leaves absorb it, turn brown, and fail to produce any impression. Pupils lose interest and get frustrated because their leaves 'aren't working'. Also, for a GCSE class, several pots of nail varnish are needed so that no one is left waiting, thus adding to expense. Prepare an epidermal impression by coating the leaf surface with nail varnish. Peel off the dried layer of nail varnish by using sellotape and stick this onto a slide. Alternatively, with some plants you can peel off an epidermal strip directly, which you can mount in water on a slide and place under the microscope. If you have an eyepiece graticule which you can use, you can work at a relatively low power, and you can count the number of stomata within different squares to act as replicates. If you do not have an eyepiece graticule, you can work at a higher magnification and count a number of different fields – the area visible under the microscope – at any one time. Make sure that: You get enough counts to be able to analyse your results statistically, You calculate the area of leaf which you are counting in order to give a quantifiable result e.g. stomata per square mm. You will need to calibrate the size of the field of view, or the size of individual squares within a field, using a stage micrometer to do this. Using 'New Skin' A good alternative is to use Germolene 'New Skin' to take the impressions. There is an excellent protocol on Measuring Stomatal Density on the Practical Biology website. Using Water Based Varnish A successful alternative to nail varnish is to use a clear water based varnish (available at 'Do it Yourself' supermarkets). A half litre tin is cheap, and can be divided up into smaller amounts for ease of use. Paint the opaque varnish thinly on to the leaf to produce a clear film. Leave it to dry as usual. These water based varnishes take longer to dry, so if the leaves are coated during one lesson, the impressions can be peeled off and examined the next. The varnish is non toxic, so can be used on living plants without removing the leaves – this means that school plants do not have to be denuded for this experiment! In addition to revealing the stomata, the cell walls also show up. Other Methods Other suggestions include producing impressions on acetate film, by placing a leaf in propanone and then pressing it onto the acetate. This does not work for some plant leaves, especially those that have an uneven surface – and the leaf still has to be removed from a plant. Another method is to rub a board pen over the surface. The solvent-based ink permeates the leaf, showing up the stomata. However, this seems to work only with certain types of pen – probably related to the strong solvent in the pen. This also raises health and safety issues. Suggestions for investigations As well as studying stomatal patterns and densities in a variety of plants, the following questions may be posed to students: Does the density vary over a leaf surface? Does the density vary between different leaves of the same plant? . . . or between different plants of the same species? (I have looked at a number of the Brassicaceae: B. oleracea v. capitata (cabbage), v. gemmifera (brussels sprout), v. italica (broccoli), v. botrytis (cauliflower). All these leaves are available from greengrocers – and you can eat the rest of the vegetable afterwards! Does the density vary between plants from different habitats. (I have used a number of cacti and succulent plants to do this.) For plants that reproduce vegetatively, is there any difference between parent and offspring? (Kalanchoe and begonias are useful here). Acknowledgements to Barry Meatyard and Mary MacDonald. Stomatal density, a critical aspect of plant biology, denotes the number of stomata, or minute apertures used for gaseous exchange, present per unit area of the leaf. This value varies across different species and can be influenced by various environmental factors. Understanding stomatal density is vital as it plays a substantial role in a plant's efficiency in water usage and its photosynthetic capacity.The Stomatal Density Calculator is an advanced tool designed with the intention to facilitate rapid and efficient calculation of stomatal density. By accepting inputs such as the number of stomata and the area under examination, it yields the stomatal density, providing a valuable resource for those engaged in plant research.See also Cloning Molar Ratio CalculatorThe calculator operates on a straightforward formula to deliver the stomatal density:Stomatal Density = Number of Stomata / AreaIn this formula, 'Number of Stomata' pertains to the count of stomata within the area being examined, and 'Area' denotes the surface area of the leaf section under study.To understand the calculator's operation better, let's consider a simple example:Suppose you have a microscopic image of a leaf section in which you've counted 500 stomata. The area of the leaf section under scrutiny is 0.5 mm^2.To find the stomatal density, you would need to input these values into the Stomatal Density Calculator. In this case, the number of stomata is 500, and the area is 0.5 mm^2.See also Cell Density CalculatorUpon entering these values and hitting 'Calculate', the calculator processes the data using the formula and promptly displays the stomatal density.This user-friendly calculator simplifies the process of stomatal density calculation, thus proving to be a beneficial tool for researchers and students alike. Stomatal density is a crucial measure in plant biology, referring to the number of stomata (pores) per unit area of plant leaves. These tiny openings allow gases like carbon dioxide and oxygen to pass in and out of the leaf, facilitating important processes such as photosynthesis and transpiration. Monitoring stomatal density helps scientists and researchers assess how plants adapt to their environment, manage water loss, and respond to various environmental stressors. This article will guide you through the Stomatal Density Calculator, a tool that makes it easy to compute stomatal density, offering a deeper insight into plant physiology and health.Stomatal density refers to the number of stomata present in a given area of a plant leaf, typically measured in stomata per square millimeter (stomata/mm^2). The stomata are microscopic pores located mainly on the leaf's surface, and their density can vary significantly between species, environmental conditions, and developmental stages of the plant. Higher stomatal density is typically observed in plants that require higher gas exchange rates, while lower densities may indicate adaptation to arid environments where water conservation is critical.The stomatal density of a plant can be influenced by several factors, including:Environmental conditions: Factors like humidity, temperature, and light availability can alter stomatal development.Water availability: Plants in dry conditions often have fewer stomata to reduce water loss through transpiration.Plant species: Different species have evolved unique stomatal densities based on their ecological niches.Our Stomatal Density Calculator is a user-friendly tool designed to help you easily calculate stomatal density. By inputting two simple values—the number of stomata in the field of view (FOV) and the area of the sample in square millimeters (mm^2)—the calculator provides the stomatal density value, which is expressed as the number of stomata per square millimeter (stomata/mm^2).To calculate the stomatal density, we use the formula:Stomatal Density = Number of Stomata / Area (mm^2)Where:Number of Stomata refers to the total number of stomata observed within a specific field of view (FOV).Area refers to the area in square millimeters (mm^2) in which these stomata are counted.This formula allows for a quick and accurate determination of the stomatal density, giving you an important measure to compare across different plant species or environmental conditions.Here's a simple step-by-step guide on how to use the Stomatal Density Calculator:Enter the Number of Stomata: In the first field of the calculator, input the total number of stomata you have observed in the sample area. This could be the count from a specific portion of the leaf, typically observed through a microscope.Enter the Area in mm^2: In the second field, input the area in square millimeters (mm^2) in which you counted the stomata. This is the size of the section of the leaf that you are studying.Click 'Calculate': After entering both values, click the "Calculate" button. The stomatal density will be displayed, indicating how many stomata are present per square millimeter.For example:If you counted 150 stomata in an area of 25 mm^2, the stomatal density would be calculated as 150 / 25 = 6 stomata/mm^2.Let's consider an example:Imagine you have counted 200 stomata in an area of 50 mm^2. By applying the formula:Stomatal Density = Number of Stomata / AreaStomatal Density = 200 stomata / 50 mm^{2}Stomatal Density = 4 stomata/mm^{2}This means the stomatal density for the observed leaf section is 4 stomata per square millimeter. The calculator will give you this result instantly once you input the data.Understanding stomatal density can be incredibly useful in various fields, including:Plant physiology research: Researchers can use stomatal density measurements to study how plants respond to environmental stressors, such as drought, high light intensity, and atmospheric carbon dioxide levels.Agricultural practices: Farmers can use this data to understand how crops adapt to their growing conditions and select plant varieties with optimal stomatal densities for certain environments.Climate studies: As stomatal density influences the rate of transpiration and carbon fixation, it's a valuable metric in studying plant adaptation to climate change.Ecological studies: Stomatal density can offer insights into the evolutionary adaptations of plants to different ecological niches.Environmental Factors: Factors like water availability, light intensity, and atmospheric carbon dioxide can influence the development of stomata. For example, plants in dry conditions tend to have fewer stomata, reducing water loss.Species-Specific Variation: Stomatal density can vary significantly between different plant species. Some plants, like those in tropical regions, may have a high stomatal density, while others, like those in deserts, may have a low density for water conservation.Microscope Use: To use the stomatal density calculator effectively, you need to count the number of stomata in a sample area. This is typically done using a microscope with a clear field of view. Make sure you use an appropriate magnification to observe individual stomata clearly.What is stomatal density?Stomatal density is the number of stomata (pores) per square millimeter on a plant's leaf.How is stomatal density calculated?It's calculated by dividing the number of stomata by the area in square millimeters.Why is stomatal density important?It provides insights into a plant's gas exchange, photosynthesis rate, and water conservation strategies.How does water availability affect stomatal density?Plants in dry conditions often have fewer stomata to reduce water loss through transpiration.Can stomatal density be used to study plant responses to climate change?Yes, changes in stomatal density can reflect how plants are adapting to altered atmospheric conditions.What instruments are used to measure stomatal density?A microscope is typically used to count the stomata in a sample area.What is a typical stomatal density value?Values can vary widely, from 1 to over 100 stomata/mm^2, depending on the plant species and environment.Can stomatal density be changed through genetic modification?Yes, genetic engineering can influence stomatal development to improve water use efficiency or enhance photosynthesis.What does a high stomatal density indicate?It usually indicates that the plant requires a high rate of gas exchange, often found in plants that grow in environments with abundant water and light.What does a low stomatal density indicate?It often suggests an adaptation to water scarcity, as the plant aims to minimize water loss through transpiration.How does light intensity affect stomatal density?Higher light intensity typically promotes a higher stomatal density to facilitate increased photosynthesis.Can stomatal density be used to differentiate plant species?Yes, it can be a distinguishing characteristic between plant species adapted to different environmental conditions.Is stomatal density related to photosynthesis rate?Yes, plants with a higher stomatal density can exchange gases more efficiently, leading to higher photosynthesis rates.How does temperature influence stomatal density?In warmer climates, plants might develop more stomata to regulate heat through transpiration.Is stomatal density the same on all parts of a leaf?No, stomatal density can vary between the upper and lower surfaces of the leaf and across different leaf regions.How do you measure the area for stomatal density calculation?The area is typically measured in square millimeters, using a standardized field of view through a microscope.Can stomatal density be affected by environmental pollutants?Yes, environmental pollutants can interfere with stomatal development, potentially reducing stomatal density.What is the relationship between stomatal density and water stress?In drought conditions, plants may reduce stomatal density to limit water loss.How can stomatal density be measured in the lab?It's typically measured by counting the number of stomata in a specific area using a microscope and applying the stomatal density formula.Can stomatal density be used to assess plant health?Yes, variations in stomatal density can indicate stress, disease, or environmental changes affecting plant health.The Stomatal Density Calculator is a valuable tool for researchers, botanists, and agriculturalists interested in understanding plant physiology and environmental adaptation. By inputting the number of stomata and the sample area, this tool makes calculating stomatal density simple and quick. Whether you're studying plant health, conducting ecological research, or improving crop production, understanding stomatal density can provide critical insights into plant function and adaptation. Test hypotheses about the influence of habitat conditions on leaf stomatal density Practice using Excel to calculate mean and SD and make properly labeled column graphs Perform t-tests to determine significant differences between two experimental groups and write an interpretation of resultsWrite the Lab Title on a new page on the right-hand side of your notebook. *Remember to include the Lab Date!*Write the Background, Aim and your Hypothesis for the Stomatal Densities labDraw Data Table 1 and Data Table 2 (See Procedures, Step 2)Add an entry for this lab in your Table of Contents.Model Organism: Leaves from Rhododendron plantsExperimental Questions: Does pollution/CO2 exposure in the habitat influence the stomatal density on Rhododendron plant leaves?Independent Variable: Plant habitatControl Group: Leaves from a woodland habitat   Experimental Group: Leaves from an city habitat close to a busy roadDependent Variable: Stomatal density (stomatal count / mm2)   I hypothesize that stomatal density in plants varies with exposure to environmental CO2 pollution, and predict that plants from busy street habitats will have significantly ___higher / lower___ stomatal density compared with plants from wooded habitats. OR I hypothesize that the stomatal density does not significantly differ based on exposure to environmental CO2 pollution.Land plants are autotrophs meaning that they produce their own for food. Plants make glucose by performing photosynthesis in their leaves. During photosynthesis, light energy and water are used to create high energy molecules (ATP and NADPH). Those energy molecules then power the reactions that convert CO2 into glucose sugars. Sunlight is absorbed by green pigments in plant leaves. Water is obtained from the ground or soil. But how do land plants acquire the CO2 they need for photosynthesis? Plants acquire CO2 through small pores called stomata (singular = stoma). The stomatal openings are surrounded by two guard cells, which swell and shrink to open and close the pore. Oxygen produced by photosynthesis can also leave the leaf through the stomata. Plants experience a challenge in this process: when they open their stomata for gas exchange, water vapor from the inside of their leaves moves out into the environment, which puts the plant at risk of drying out.The number or density of stomata on leaves allows the plant to exercise some control over environmental conditions. Given the role of stomata in plant leaves, how do you think stomatal densities differ between plants native to wet versus dry habitats? Sunny versus shady habitats? What about polluted versus not-polluted habitats?We can measure stomatal density on leaves by creating stomatal peels. This involves making an 'impression' of the stomata of a leaf by using clear nail polish. We can then attach the peel to a microscope slide and count the number of stomata present. If we use calculations to standardize the counts to stomatal density (the number of stomata per mm2 of leaf) we can then compare leaves from different habitats. To test our hypothesis about the influence of habitat CO2 on stomatal density, we will compare leaves collected from plants next to a busy street to those collected from a natural wooded area. We will make stomatal peels, perform counts, and calculate stomatal densities from replicate leaves in each habitat. We will then compare stomatal densities from the two habitats by creating a figure and performing a t-test.1. With your partner, select 5 leaves of each habitat type. Determine which partner will be responsible for counting stomata on each leaf type.2. Using clear nail polish, paint a thick 'coat' of polish roughly 1.5cm2 on the ventral (under) surface of each leaf.3. Allow the clear nail polish to dry for 5 minutes. 4. While waiting for the nail polish to dry, set up your microscope and measure the field of view (see next section) and obtain 5 clean microscope slides.5. Once dry, take 5 pieces of packing tape and stick over each of the 5 nail polish 'stomatal peels.'6. Gently peel back the tape to lift the nail polish to reveal the 'stomatal peels.'7. Carefully stick each stomatal peel onto a separate microscope slide. Trim with scissors where necessary.PreLab Prep! Draft these two tables in your lab notebook:1. Set up your compound microscope and place a square grid microscope slide in the stage clips. 2. Focus on the grid slide using the 4X objective (40X magnification). Count the number of mm grid squares across your microscope field of view. This is your field of view diameter at 40X. Record is value in Table 1 [A]. 3. Perform the calculations Table 1 to determine the field of the diameter [B], radius [C], area [D] and multiplication factor [E] at 400X magnification. You will use the multiplication factor [E] later.Now you are ready to count stomata!4. Focus on your stomatal peel slide first using the 4X objective, then move to the 10X objective, and finally 40X objective (400X magnification). Check with your instructor that you are looking at stomata! 5. Move into the center of your leaf impression to ensure your field of view does not include any damaged edges.6. Once focused at 400X magnification, without moving the stage, count all the stomata in the field of view. 7. Record the stomatal count in Table 2. Convert to stomatal density (stomata per mm2) by multiplying the count by your multiplication factor [E].8. Repeat counts and stomatal density calculations for your remaining slides. You will pool data with your partner and then the class to create graphs and test your hypothesis about differences in stomatal density between the two habitats. You may choose to perform stomatal counts to further explore plant diversity. For example, you could expand the experiment from this lab to compare samples from a same plant species living in different habitats. Or perhaps you are interested in comparing plants that are from very different native habitats (e.g. desert plants, rainforest plants, plains plants, water plants)... Author: Calculator Academy Team Last Updated: July 31, 2023 Enter the number of stomata in the FOV and the area (mm^2) into the Stomatal Density Calculator. The calculator will evaluate and display the Stomatal Density. The following formula is used to calculate the Stomatal Density. Where Ds is the Stomatal Density (stomata/mm^2) #S is the number of stomata in the FOV A is the area (mm^2) To calculate the stomatal density, simply divide the number of stomata in the field of view by the area. The following example problems outline how to calculate Stomatal Density. Example Problem #1: First, determine the number of stomata in the FOV. The number of stomata in the FOV is given as: 365. Next, determine the area (mm^2). The area (mm^2) is provided as: 3. Finally, calculate the Stomatal Density using the equation above: Ds = #S / A The values given above are inserted into the equation below: Ds = 375 / 3 = 125 (stomata/mm^2) Example Problem #2: For this problem, the variables needed are provided below: number of stomata in FOV = 753 area (mm^2) = 38 This example problem is a test of your knowledge on the subject. Use the calculator above to check your answer. Ds = #S / A = ? A study reveals a mean count of 16 stomata per field of view at a magnification of × 400. The stage micrometer calculates the diameter of the field of view at a magnification of × 400 to be 0.46mmCalculate the stomatal density based on these data. Give units in stomata per mm2Use a value of π = 3.14 and give your answer to the nearest whole number of stomata.Answer:Step 1: Calculate the radius of the field of viewRadius = Diameter ÷ 2Radius = 0.46 mm ÷ 2 = 0.23 mmStep 2: Calculate the area of the field of viewArea = πr2 = π × 0.232Area = 0.1662 mm2Step 3: Divide the mean number of stomata by the area of the field of view to calculate densityDensity = 16 ÷ 0.1662 = 96.27 stomata per mm2Step 4: Round to the required precision (nearest whole number)Density = 96 stomata per mm2Page 2There are several environmental conditions that have an impact on the rate of transpiration or water uptakeAir movementHumidityLight intensityTemperatureThe table below explains how these four factors affect the rate of transpiration when they are all high; the opposite effect would be observed if they were lowFactors Affecting the Rate of Transpiration TableInvestigating the effect of environmental factors on the rate of transpirationWe can investigate the effect of different environmental conditions (such as temperature, humidity, light intensity and wind movement) on the rate of transpiration using a piece of apparatus called a potometerThere are 2 types of potometer:A mass potometer measures a change in mass of a plant as a measure of the amount of water that has evaporated from the leaves and stemA bubble potometer measures the uptake of water by a stem as a measure of the amount of water that is being lost by evaporation consequently pulling water up through the stem to replace itThere are 2 different types of potometer that could be used to investigate the effect of environmental conditions on transpirationApparatusPotometer (bubble or mass potometer)TimerLampRulerPlantMethodCut a shoot underwaterTo prevent air entering the xylem and place in tubeSet up the apparatus as shown in the diagram and make sure it is airtight, using Vaseline to seal any gapsDry the leaves of the shootWet leaves will affect the resultsRemove the capillary tube from the beaker of water to allow a single air bubble to form and place the tube back into the waterSet up a lamp 10 cm from the leafAllow the plant to adapt to the new environment for 5 minutesRecord the starting location of the air bubbleLeave for 30 minutesRecord the end location of the air bubbleChange the light intensityReset the bubble by opening the tap below the reservoirRepeat the experimentCalculate the rate of transpiration by dividing the distance the bubble travelled by the time periodThe further the bubble travels in the same time period, the greater the rate of transpirationCalculating the rate of transpiration using a bubble potometerInvestigating transpiration rates using a potometerOther environmental factors can be investigated in the following ways:Airflow: Set up a fan or hairdryer to blow air over the plant (this investigation can be extended by putting the fan at different distances from the plant or at different fan-speed settings)Humidity: Spray water in a plastic bag and enclose the plant within the bagTemperature: Change the temperature of room (e.g. cold room or warm room)ResultsAs light intensity increases, the rate of transpiration increasesThis is shown by the bubble moving a greater distance in the 30 minute time period when the lamp was placed closer to the leafTranspiration rate increases with light intensity because more stomata tend to be open in bright light in order to maximise photosynthesisThe more stomata that are open, the more water can be lost by evaporation and diffusion through the stomatal poresLimitationsThe potometer equipment has a leakSolution: Ensure that all equipment fits together rightly around the rubber bungs and assemble underwater to help produce a good sealThe plant cutting has a blockageSolution: Cut the stem underwater and assemble equipment underwater to minimise opportunities for air bubbles to enter the xylemThe potometer has shown no change during the experimentSolution: Use the plant cuttings as soon as they have been cut, as transpiration rates may slow down when the cuttings are no longer freshPage 3There are a wide range of factors that influence the heart rate of an organismExperiments can be designed to investigate the effect of a named variable on an organism's heart rateThese experiments are commonly done using humansSerious care needs to be taken during these experiments to ensure that no test subjects are harmedSome of the factors that can influence heart rate include:ExerciseDrugsCaffeineAlcoholSexWeightHeightTemperatureDietDehydrationWhen designing experiments investigating a single factor, it is essential to try and control the other variablesHeart rate monitorStationary exercise bike (at a set resistance level)One group of healthy humansUse the heart rate monitor to record the heart rates of each individual while at restThese results can be used to calculate the mean heart rate of the group as well as the range of resting heart rates for the group prior to exerciseAsk each individual to cycle at a vigorous pace on the stationary exercise bike for a set period of timeIt may be that the individuals are asked to maintain a particular RPM (revolutions per minute) while on the bike for 5 minutesAfter the five minutes of exercise is over, use the heart rate monitor to record the heart rates of each individualThese results can be used to calculate the mean heart rate of the group as well as the range of resting heart rates for the after exercisePresent the results in a graph or table formCare needs to be taken when selecting the exercise intensityIf the intensity is too low, it may not have an effect on the heart rateIf the intensity is too high, it could but the safety of individuals at riskIt is very difficult to ensure that individuals within a sample group are sufficiently similarBy using the same group for the before and after measurements this is not as much of an issueIf multiple groups were used care would need to be taken to find individuals with a similar life history (same sex, age, weight and height etc.)Exams may ask about the safety and ethical considerations when studying the heart rates of humans. An experiment should be designed so that the safety of any of the subjects is never at risk, for example they should not be pushed to exercise at such an intensity that could cause a heart attack.We can investigate the production of carbon dioxide and heat from respiration through experiments using germinating seeds or other living organisms such as woodliceBoiling tubesRubber bungsHydrogen carbonate indicator solutionCotton woolGlass beadsGerminating seedsBoiled/dead seedsMeasure out 10 cm3 of hydrogencarbonate indicator into 3 boiling tubesPut in a layer of cotton woolPlace 10 germinating seeds in tube APlace 10 boiled/dead seeds in tube BPlace 10 glass beads in tube CSeal each tube with a rubber bungAfter 3 hours, observe the colour of the indicatorHydrogencarbonate indicator is orange in atmospheric CO2 levelsIn high CO2 levels the indicator absorbs the CO2 and becomes yellowIn low CO2 levels it loses CO2 and becomes purpleColour results for hydrogen carbonate indicatorResultsIn this investigation, we would expect to note the followingTube A should turn yellow as the seeds are respiring and producing carbon dioxideTube B should remain orange as the dead seeds produce no carbon dioxideTube C should remain orange as there is no living material in thereExperiment to demonstrate the production of carbon dioxide by living material during respirationPractical investigation: demonstrating the production of heatApparatusVacuum FlasksThermometerCotton woolGerminating seedsDead/boiled seedsMethodSet up the flasks as shown in the diagramFlask A with the germinating seedsFlask B with the dead seedsMake sure the cotton wool is plugging the top of each flaskHold the thermometer in place with the cotton woolInvert the flaskRecord the initial temperatureAfter 4 days, record the final temperatureExperiment to demonstrate the production of heat by living material during respirationResultsThe thermometer in the flask with the germinating seeds (Flask B) should show an increase in temperatureFlask A should remain at room temperatureThis is because the seeds in flask B are respiring and producing heat energy in the processThis shows that respiration is an exothermic reactionThe seeds in flask A are not respiring because they are dead, so the temperature remains the sameDid this page help you? The concept of stomatal density is pivotal in the fields of botany and plant physiology, offering insights into plant-environment interactions, water use efficiency, and photosynthetic capabilities. Stomatal density, defined as the number of stomata per unit area, varies widely among species and is influenced by environmental conditions during development. Historical Background Stomata are microscopic pores on the surface of leaves and stems through which plants exchange gases with their environment. The study of stomatal density has historical roots extending back to the early days of microscopy, but it has gained increasing importance with our growing understanding of plant response to environmental stressors and climate change. Calculation Formula The stomatal density is calculated using the formula: \[Ds = \frac{S}{A} \] where: \(Ds\) is the stomatal density (stomata/mm^2), \(S\) is the number of stomata in the field of view (FOV), \(A\) is the area in mm^2. Example Calculation Consider a scenario where you observe 150 stomata within a field of view that encompasses an area of 0.5 mm^2. The stomatal density is calculated as: \[Ds = \frac{150}{0.5} = 300 \, \text{stomata/mm^2} \] Importance and Usage Scenarios Stomatal density data is critical for understanding how plants adapt to their environment, with implications for agricultural practices, ecosystem management, and climate change research. It helps scientists and agronomists develop more drought-resistant crop varieties and understand how vegetation interacts with the atmosphere. Common FAQs What affects stomatal density? Stomatal density can be influenced by a variety of factors including light intensity, atmospheric CO_2 levels, water availability, and developmental stage. How does stomatal density relate to plant efficiency? Higher stomatal densities can increase photosynthetic capacity and transpiration rates, but may also lead to greater water loss. There's often a trade-off between water use efficiency and carbon gain. Can stomatal density change in response to environmental conditions? Yes, some species can adjust their stomatal density as they grow in response to changing environmental conditions, a phenomenon known as phenotypic plasticity. This calculator serves as a tool for educators, students, and researchers in plant sciences, facilitating the easy computation of stomatal density, an important parameter in understanding plant physiology and ecology. This technique is straightforward, but requires care to achieve good results. Stomatal density usually varies between the upper and lower epidermis of any leaf, will vary from species to species, and may change with carbon dioxide concentration in the surrounding atmosphere and with light intensity. Any change will take several weeks to occur, so there is an opportunity here for a long-term, self-directed investigation. Mathematical analysis of the data gathered may be a challenge for some students – but is simplified with a spreadsheet such as the one to be downloaded below. Lesson organisation Demonstrate the technique and give students an opportunity to practise the skill of making epidermal peels or impressions. Supply students with plants kept for several weeks under controlled conditions (such as varying CO2 level, water supply, humidity, temperature or light intensity) or offer this as the groundwork for a longer-term self-directed investigation for students. This stomatal density calculation spreadsheet (15 KB) calculates the area of the field of view for an input radius, and calculates stomatal density. This shows all students how spreadsheets can help with this kind of number work in science, and will support students whose mathematical skills are weak. Apparatus and Chemicals Microscope with eyepiece graticule (calibrated for different magnifications) or stage graticules on microscope slides to allow simple measurement of field of view (Note 6) Nail varnish and sellotapeor Germolene 'New skin' to take impressions from the epidermis Plants to investigate (Notes 1 and 2) Health & Safety and Technical notes Plant sap can be irritating to the skin. Students may have allergic reactions to nail varnish or Germolene 'New skin'. Read our standard health & safety guidance 1 Plants with hairy leaves plants are not suitable for taking impressions. Spider plants (Chlorophytum comosum) work well in this procedure. Red hot poker (Kniphofia) is a common garden plant; this monocotyledonous example is easy to study, because you can peel its epidermis and view it directly under a microscope. Grey willow (Salix cinerea) has been studied in modern and fossil forms. Also useful are the Mexican hat plant (Kalanchoe diagremontiana), and Arabidopsis thaliana - this is a popular model organism for plant biology and genetics; it has one of the smallest plant genomes and was the first plant genome to be fully sequenced. Pot geranium (Pelargonium) is also easy to study and you can tear sections of epidermis for direct viewing. Variegated Tradescantia leaves can be used for direct viewing of stomata in the regions with little or no chlorophyll. 2 Grow plants under clear domes taped to a bench or tray so you can control the atmosphere around them. You could use a large plastic water container, a plastic garden bell cloche or a laboratory bell jar. Include a thermometer in each dome so you can monitor temperature. Reduce humidity levels by including a desiccant such as silica gel or calcium chloride (Note 3). Increase humidity levels by including an open vessel of water (such as a deep Petri dish), and topping it up regularly before the liquid evaporates fully. Reduce light levels by covering domes with increasing numbers of layers of fine fabric or horticultural fleece. The level of carbon dioxide in normal atmospheric air is low, but plants will produce some from their metabolic processes. You could increase the carbon dioxide level by breathing into the dome, or adding a boiling tube with a few marble chips (calcium carbonate) and 10-20 cm3 of dilute hydrochloric acid (approximately 0.1 M). You could reduce carbon dioxide levels by including a carbon dioxide absorber such as soda lime (Note 4). 3 Desiccants: Silica gel (see CLEAPSS Hazcard), for users in year 7 advises wearing gloves and to beware of dust from blue (self-indicating) silica gel. The advantage of blue moisture-indicating gel (containing < 0.5% cobalt(II)chloride) is that it can be reheated and used again. The risk to health from cobalt(II)chloride is very low. Calcium chloride (see CLEAPSS Hazcard) is an IRRITANT as a solid. Wash hands immediately if any gets on the skin and wear eye protection when handling the powder or granules. 4 Carbon dioxide: Calcium carbonate is described as LOW HAZARD on its CLEAPSS Hazcard. Hydrochloric acid (See CLEAPSS Hazcard) at low concentrations presents a minimal hazard to students, and will be neutralised as the marble chips dissolve. Soda lime is described as CORROSIVE on its CLEAPSS Hazcard. Ensure that students do not handle the soda lime. Students should wear eye protection if there is any risk of getting soda lime in their eyes. Be aware of the first aid response should any soda lime get into anyone's eyes. 5 Make an epidermal impression by spreading a thin layer of nail varnish on the leaf and leaving it to dry. Remove the layer of varnish by attaching clear sticky tape to it, peeling it from the leaf surface and sticking it to the slide. You could try Germolene 'New skin' as an alternative to nail varnish. It has slightly different elastic properties and may make a clearer impression. You won't need to use sticky tape with 'New skin'. 6 Graticules printed on plastic are available at reasonable prices – around £20 for 10 – if your microscopes are not already equipped with them. Ethical issues There are no ethical issues associated with this procedure. Procedure SAFETY: Be alert to any students suffering allergic responses to the materials handled. Offer gloves as skin protection if necessary, and make sure students wash their hands thoroughly at the end of the procedure. Preparation a Grow plants in different conditions for 4-6 weeks. Useful varieties of plants are suggested in Note 1. Ideas for creating different conditions for the plants are suggested in Note 2. b Make sure students know what stomata look like, and understand something about their function in the plant. Investigation c Collecting epidermal evidence: the epidermis will peel from some leaves quite readily. First cut the leaf. Use your fingernails to catch hold of and peel off the epidermis, or use a sharp razor blade to peel off the epidermis. Mount the peel in a drop of water on a microscope slide with a coverslip. Alternatively, make an epidermal impression with nail varnish or another clear substance, and place that on a microscope slide to view it (Note 5). d Discuss and decide how many impressions or epidermal samples should be taken and from where on each plant to get a representative sample. Try to be consistent about which part of the leaf to use. e View the epidermal impressions using a calibrated microscope fitted with an eyepiece graticule (Note 6). f Calculate the true area of the field of view. You can calculate this using the formula area = πr2, when you have measured the true radius of the field of view (r). g Count the stomata visible in each of three areas of the impression. h Calculate the stomatal density for each area of the impression sampled. i Analyse average density for each impression and for each plant. j Download this stomatal density calculation spreadsheet (15 KB) to help you calculate area of field of view, stomatal density for each impression, and average stomatal densities. Teaching notes Stomata control the movement of gases and vapours into and out of a leaf. They are often discussed primarily in the context of controlling loss of water from a leaf – as shortage of water is a common stress experienced by plants. The stomata of wilting plants close which minimises further water loss from the leaf. However, closed stomata will also reduce the availability of carbon dioxide for a photosynthesising leaf. So at low concentrations of carbon dioxide, in light conditions, stomata are stimulated to open wide which permits photosynthesis to continue. In low light conditions, carbon dioxide concentration is not a limiting factor for photosynthesis and stomata can be closed without affecting carbon dioxide uptake. Over short time scales, reducing the size of the aperture in each stoma reduces the loss of water vapour from a leaf, but also reduces the amount of carbon dioxide that the plant can absorb. Therefore, at high light intensities (which are often accompanied by high temperatures and low water levels) reducing water loss has the concomitant effect of limiting photosynthesis. Some species of plant have stomata on both sides of the leaf, and others have stomata only on the lower epidermis. The shape of stomata (and the mechanisms for controlling the size of the aperture) differ between monocotyledonous plants (such as grasses) and dicotyledonous plants. Some species seem to respond to prolonged ambient levels of light intensity and carbon dioxide by developing leaves with an altered density of stomata. For example, at high CO2 levels, a lower density of stomata will not limit the rate of photosynthesis, but will reduce water loss. At higher light intensities, a higher density of stomata will maximise the rate of photosynthesis, but with the risk of enhanced water loss. Interaction between factors is complex and varies from species to species. A literature search will find many suggestions of factors already investigated which could promote ideas for further work in the school/ college laboratory. Studies of stomatal density of plant samples up to 300 years old in botanical libraries have been used alongside evidence of recent changes in carbon dioxide levels in the atmosphere. Studies of stomatal density in fossils has been correlated with information from ice cores to give evidence of how carbon dioxide levels in the atmosphere have affected plants in the past. (See Annals of Botany.) There are commercial implications when stomatal density changes in plants grown under artificial light or with additional atmospheric CO2 to improve crop production. This is because stomatal reaction to high light intensity or high CO2 levels alter their water requirements, and the cost of supplying water to the plants. Health & Safety checked, October 2008 Downloads Download this stomatal density calculations spreadsheet (15 KB) to help your students manage the calculations in this procedure. Web links www.saps.org.uk/students/supporting-materials/543-seeing-without-eyes-how-plants-learn-from-light-an-article-for-post-16-students SAPS 'Seeing without eyes – how plants learn from light' by Stephen Day is an 8-page booklet explaining how phytochromes in plants react to light intensity and provide a mechanism for plants to respond to light. SAPS plant science images database with images of stomata from dicotyledonous plants such as Kalanchoe lower epidermis and Arabidopsis thaliana. Abstract of Annals of Botany 76: 389-395, 1995. 'Stomatal density and index of fossil plants track atmospheric carbon dioxide in the Palaeozoic' by Jennifer C. McElwain and William G. Chaloner. This research correlates the stomatal density of forest tree species collected over the last 200 years with changes in carbon dioxide levels in the atmosphere. It goes on to link stomatal density in fossil specimens from the Palaeozoic with carbon dioxide levels as deduced from ice cores. (Websites accessed October 2011) blovy Published in Plant Anatomy 3 mins read Mar 27, 2025 Stomatal density is calculated by determining the number of stomata within a known area on a leaf's surface, typically using a microscope. Here's a step-by-step guide: Steps to Calculate Stomatal Density Calculate the Radius of the Field of View: This involves determining the radius of the circular area you are viewing through the microscope. The radius is half the diameter. You can use a stage micrometer to calibrate your microscope and accurately measure the diameter of the field of view at a specific magnification. Calculate the Area of the Field of View: The area of the circular field of view is calculated using the formula for the area of a circle: Area = πr^2, where 'π' (pi) is approximately 3.14159, and 'r' is the radius of the field of view. Count Stomata and Determine the Mean: Choose several fields of view: Select multiple, representative areas on the leaf sample under the microscope. Using multiple fields of view will give you a more accurate density estimate. Count the number of stomata in each field of view. Calculate the mean number of stomata per field of view by summing the number of stomata from each field of view and dividing by the number of fields of view counted. For example, if you counted 10, 12, and 14 stomata in three different fields of view, the mean would be (10 + 12 + 14) / 3 = 12 stomata. Calculate Stomatal Density: Divide the mean number of stomata per field of view by the area of the field of view. Stomatal Density = (Mean Number of Stomata) / (Area of Field of View) This will give you the number of stomata per unit area (e.g., stomata per mm^2). Round to the Required Precision: Round the calculated stomatal density to the degree of precision needed (e.g., the nearest whole number, one decimal place, etc.). Example Let's say: The radius of your field of view is 0.5 mm. The area of your field of view is π * (0.5 mm)^2 ≈ 0.785 mm^2. The mean number of stomata per field of view is 15. Then, the stomatal density would be: Stomatal Density = 15 stomata / 0.785 mm^2 ≈ 19.1 stomata/mm^2. Rounded to the nearest whole number, the stomatal density is approximately 19 stomata/mm^2.