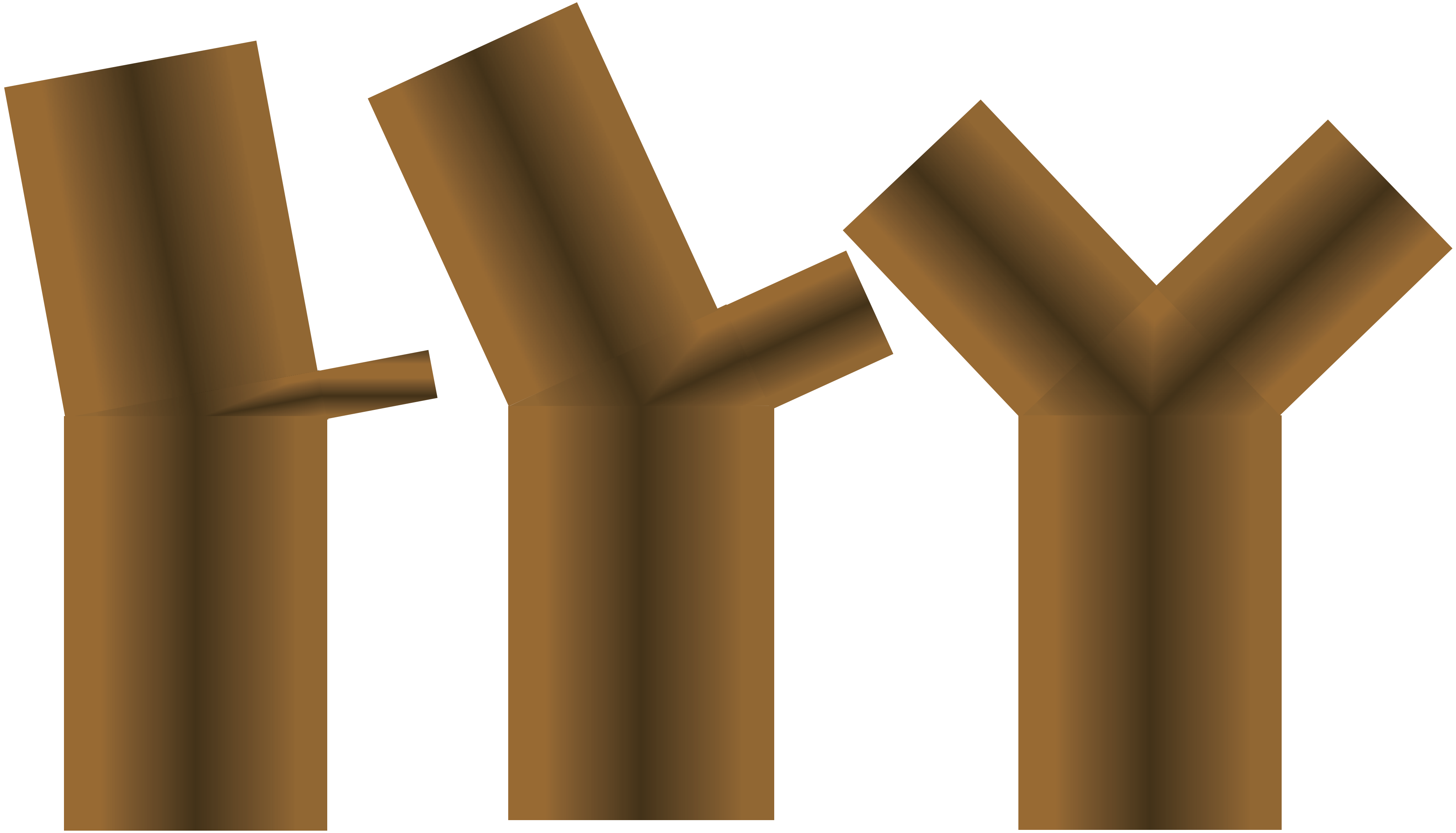
枝分かれの枝の太さは三角定規で決めよう！
Let's determine thickness of branches with a triangle!



by A. Sumida Ver. 120607

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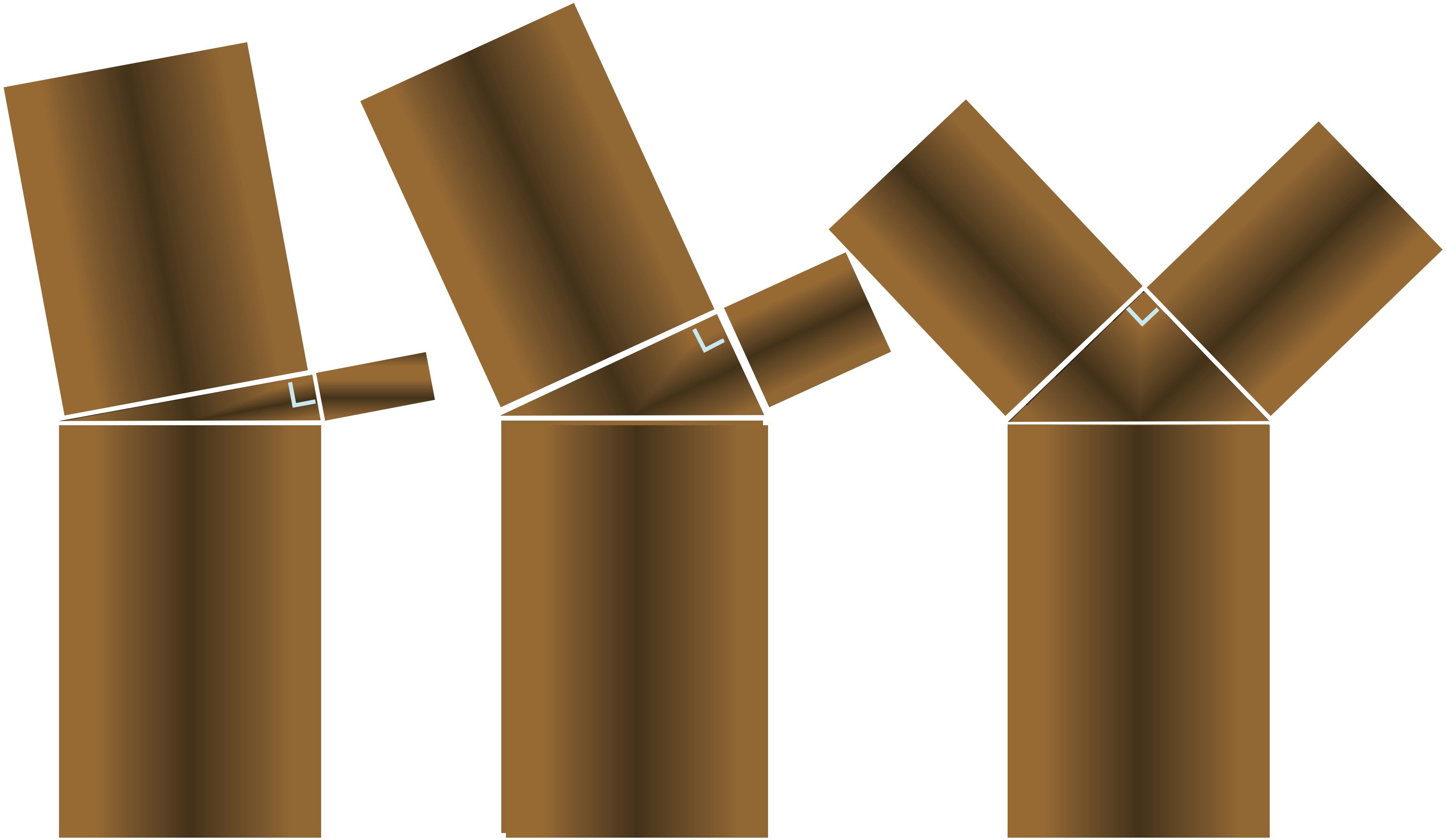
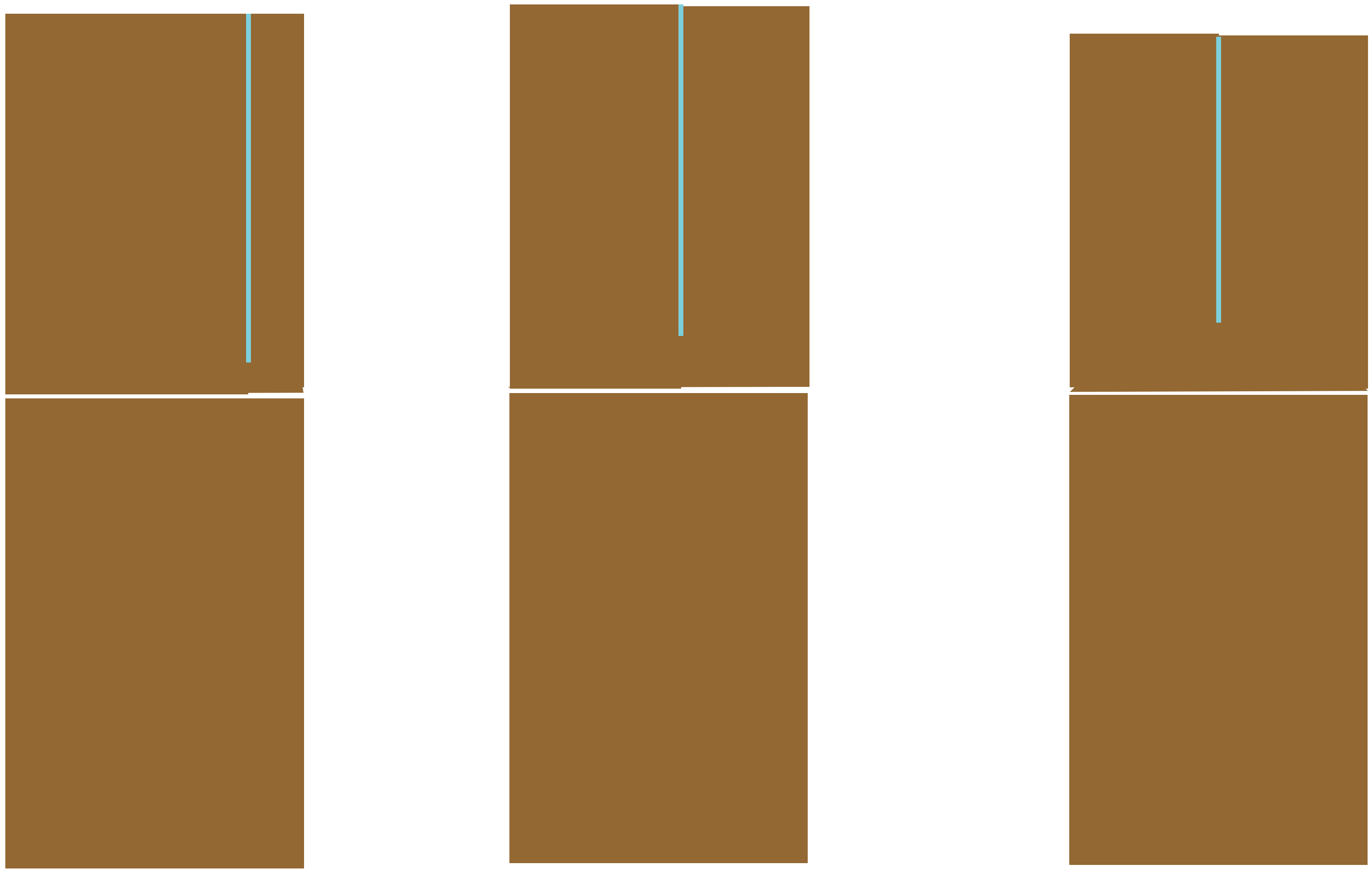


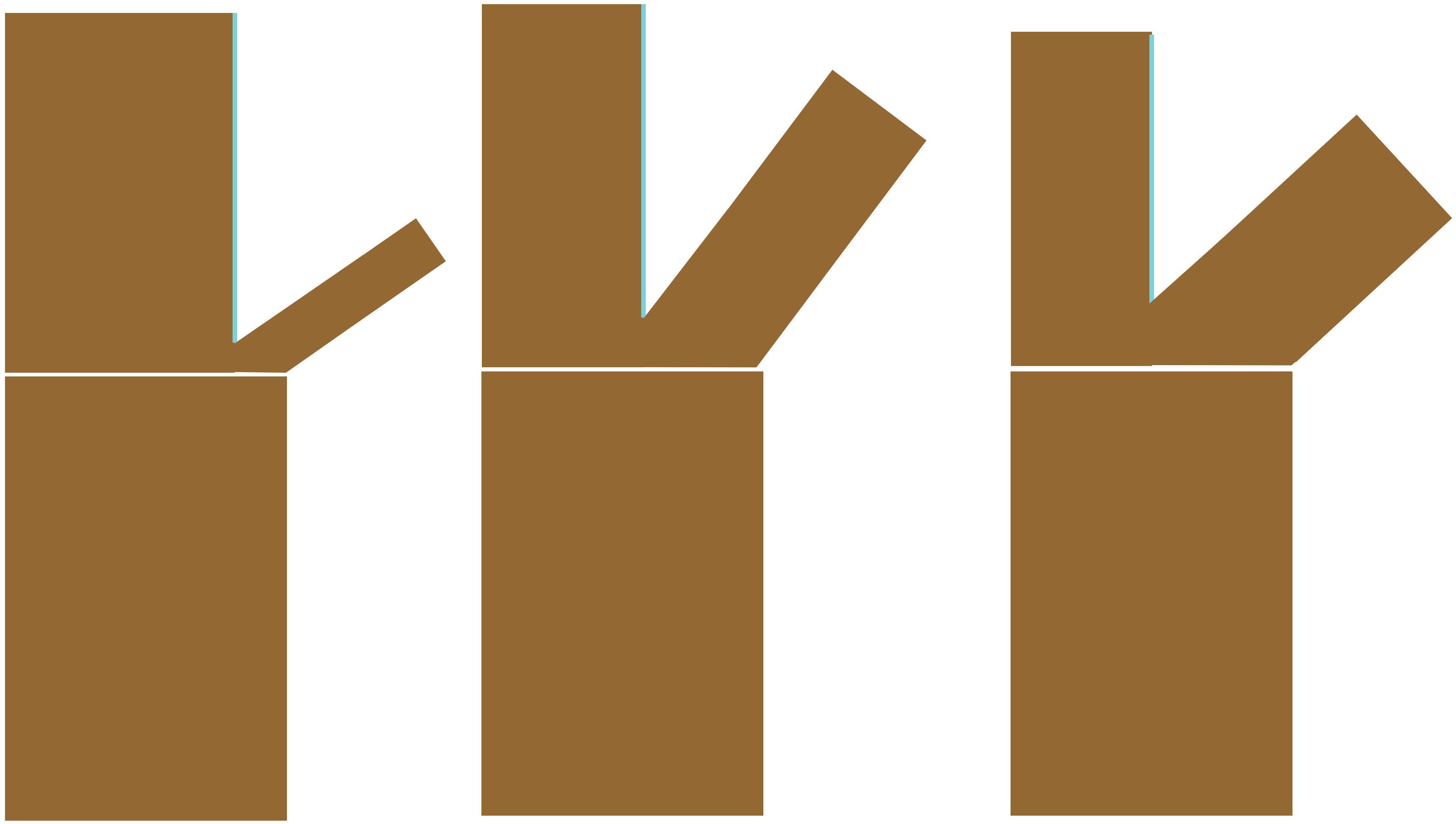
by A.Sumida Ver. 120607

枝分かれを描くときよくやるまちがい；
まず切れ込みをいれて～
A false way of drawing branch forking;
Cutting a stem, and . . .



広げる。

Opening them.

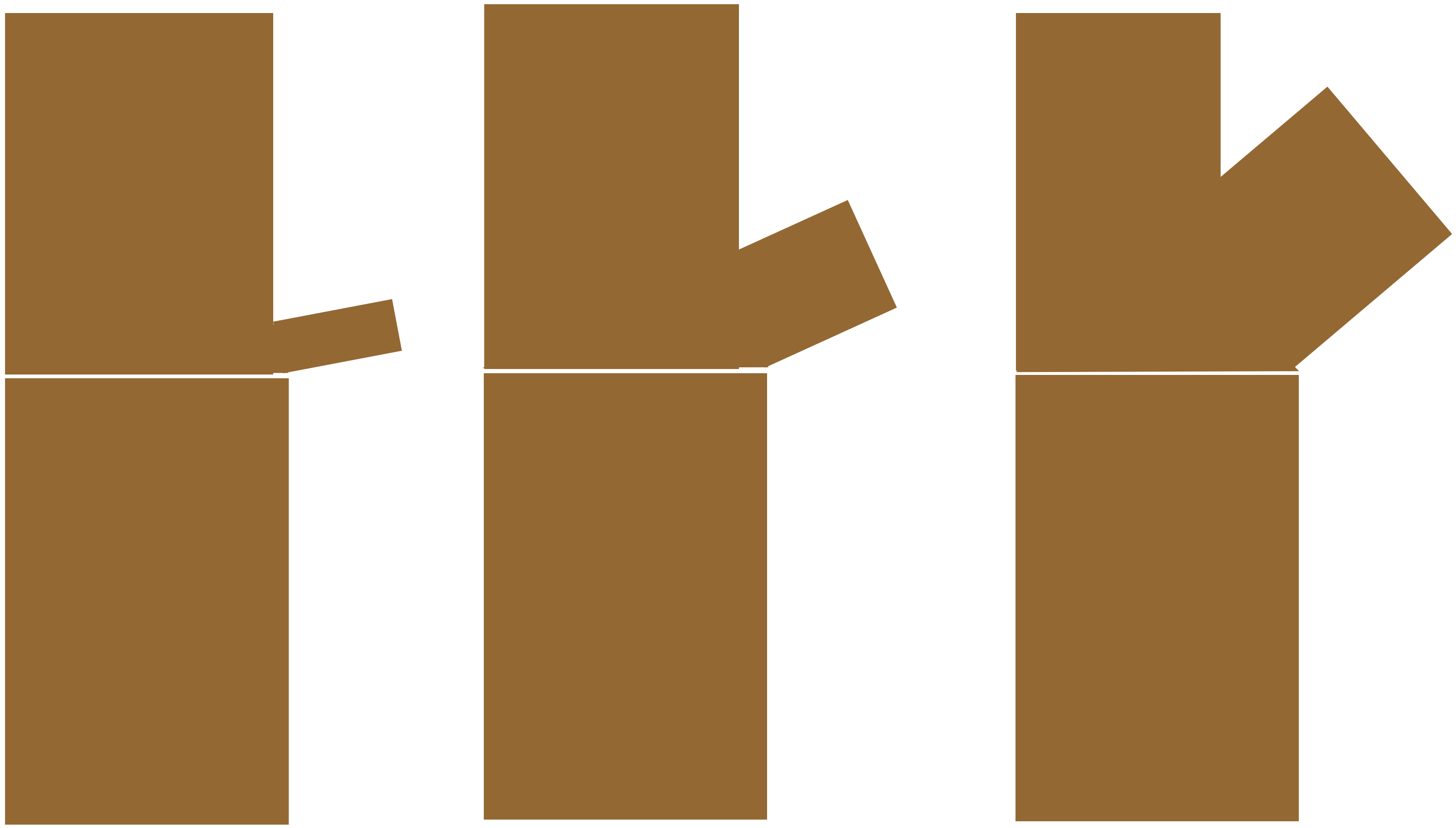


広げる。
Opening them.

でも、枝が太いと不自然に見えません？
But branching may not appear natural as a branch is thicker.

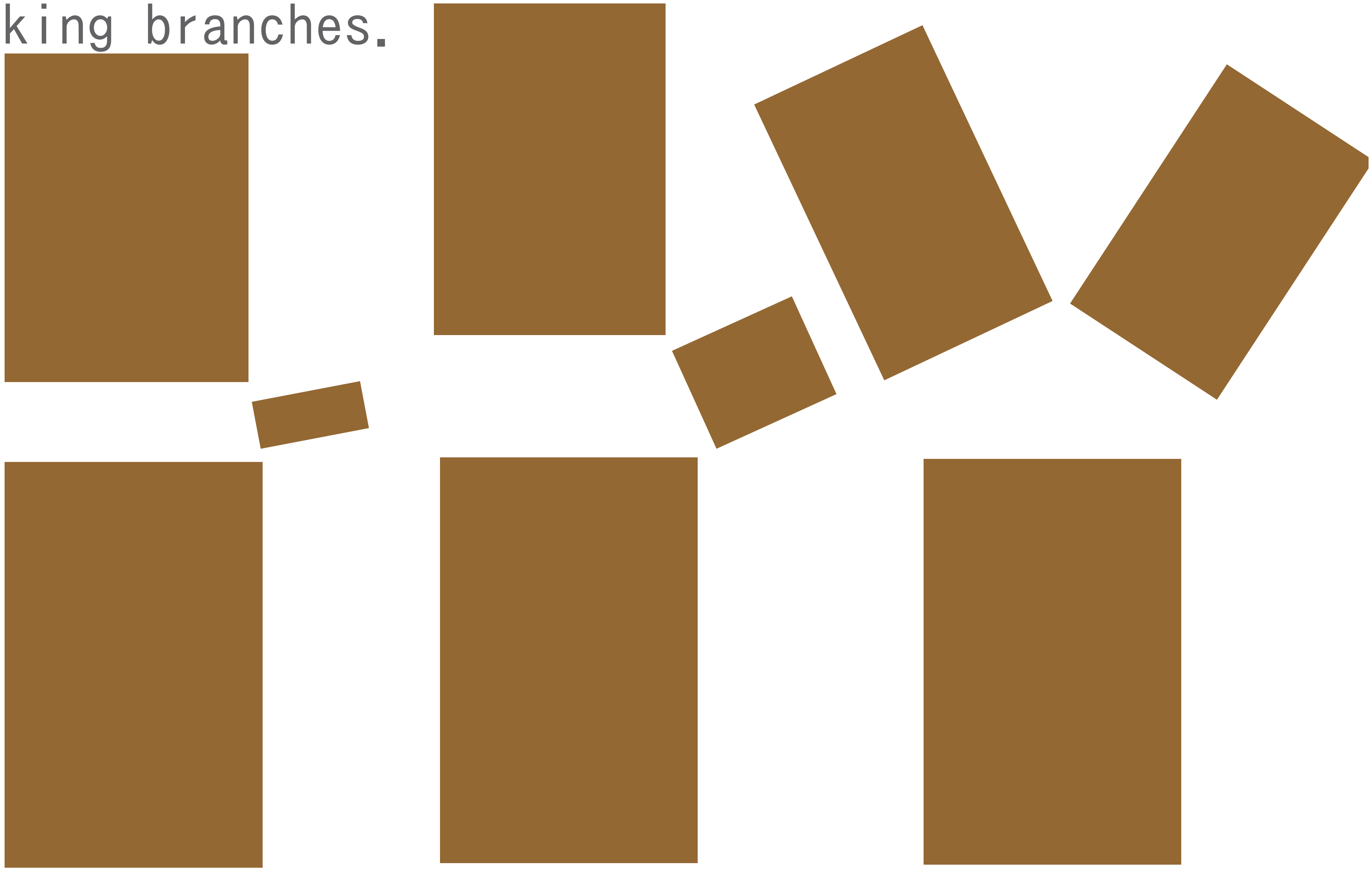
ここでは枝の角度は関係ありません。Here I'm not talking about inclination of branches.

実はこれが本当っぽい太さにした枝分かれです。
Actually, below is a more realistic pattern of thicknesses in branch forking.



ここでは枝の角度は関係ありません。Here I'm not talking about inclination of branches.

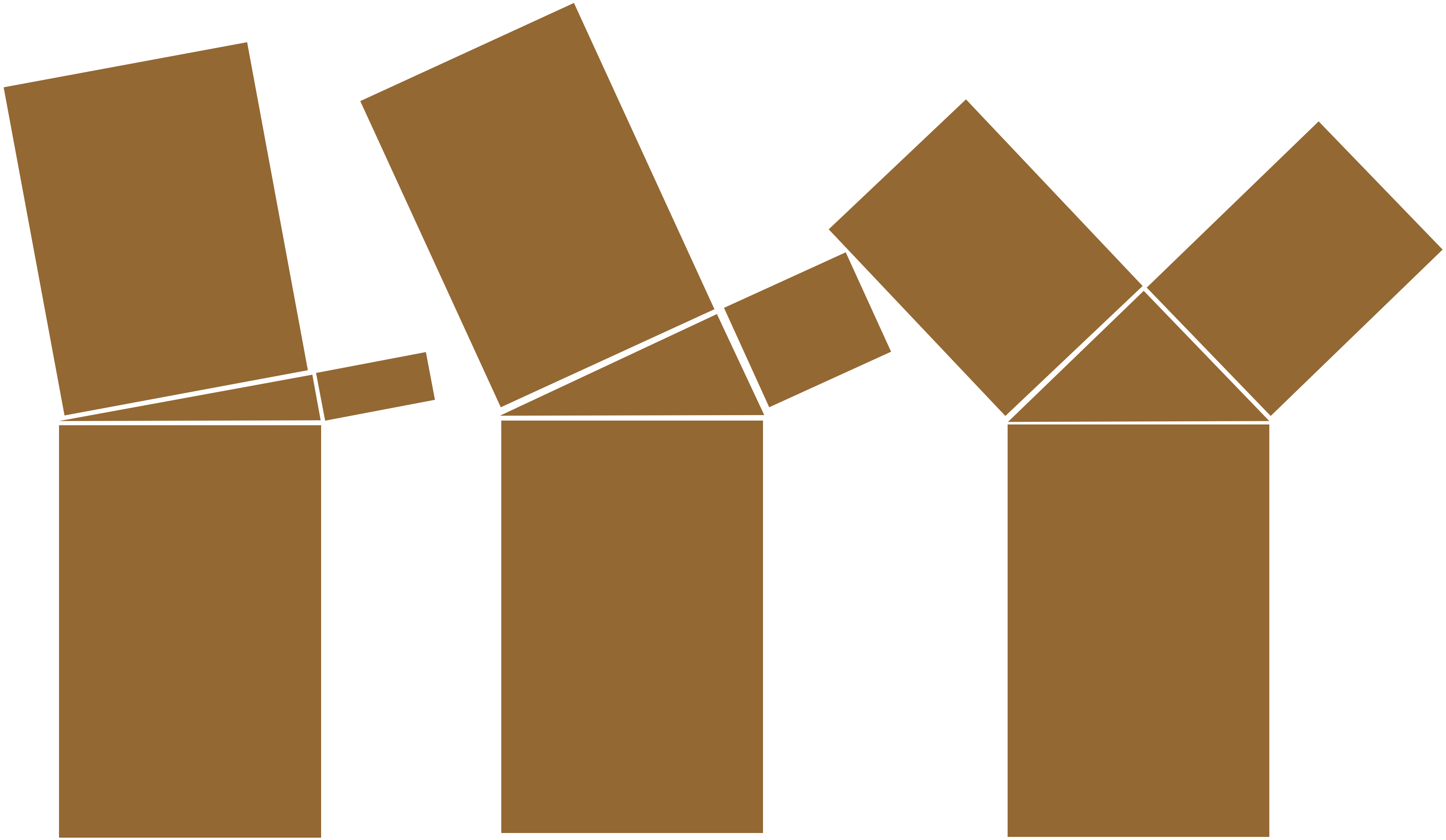
枝分かれ後の枝の太さをどう決めるかを説明します。
I’ll show you how to determine thickness of forking branches.



ここでは枝の角度は関係ありません。Here I'm not talking about inclination of branches.

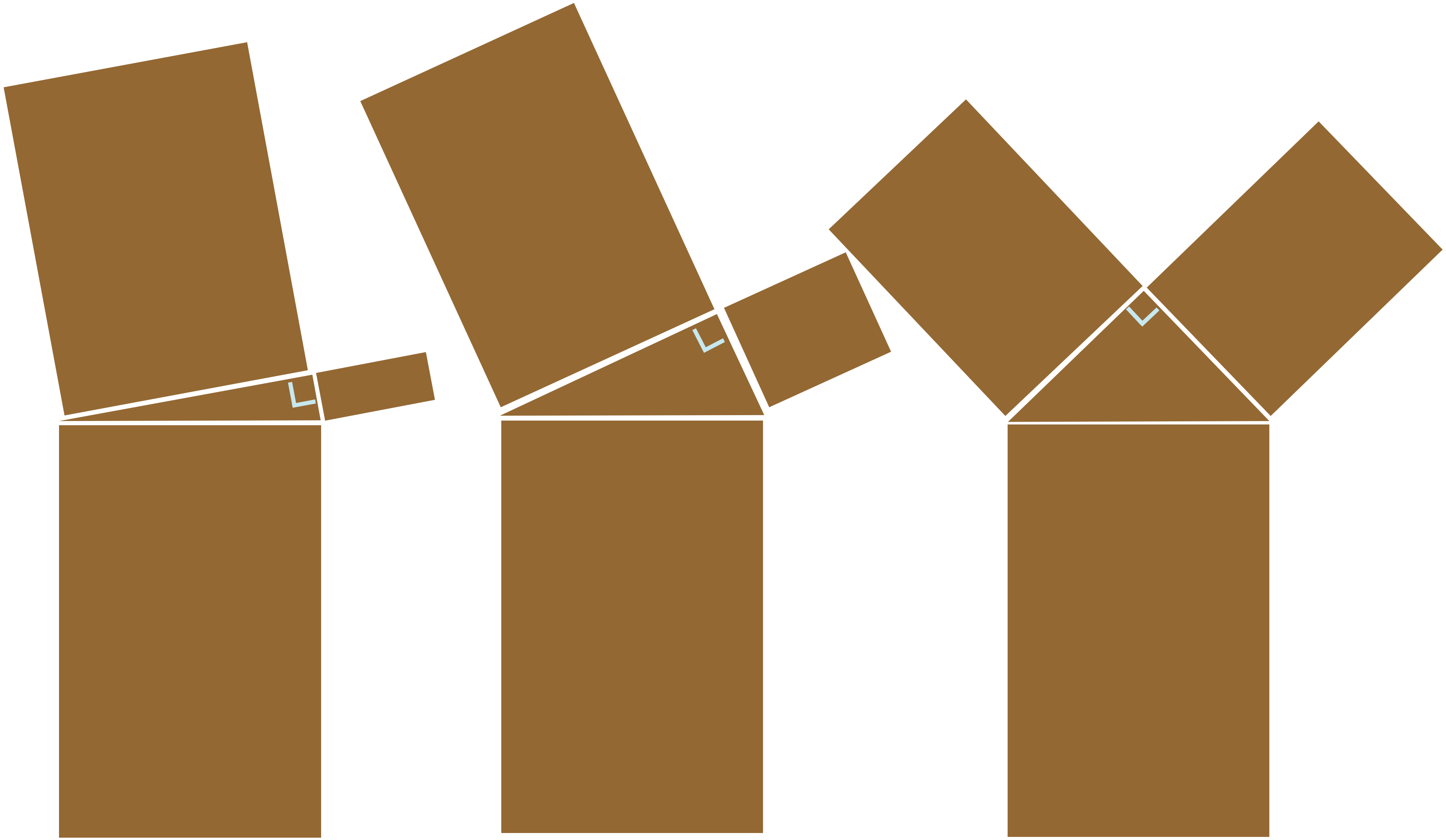
幹と枝の継ぎ目の形に注目してください。

Look at the shape of the junction of branching.

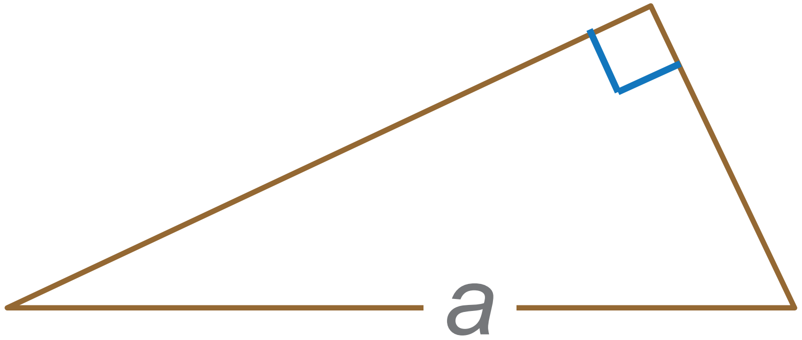


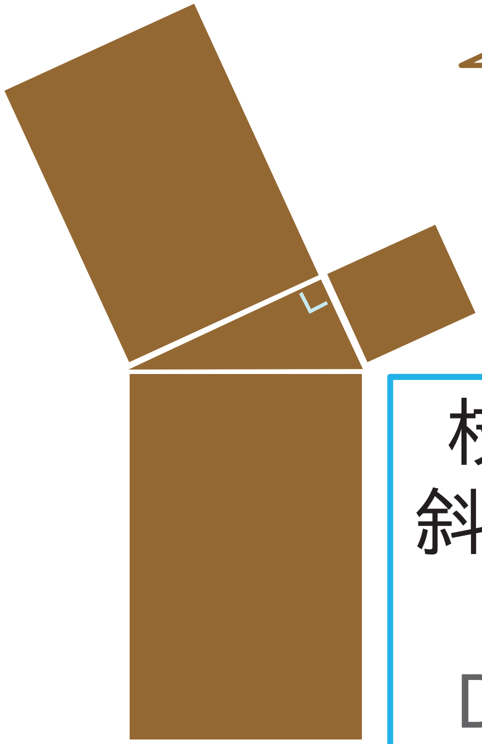
ここでは枝の角度は関係ありません。Here I'm not talking about inclination of branches.

直角三角形です。
That's right triangle.



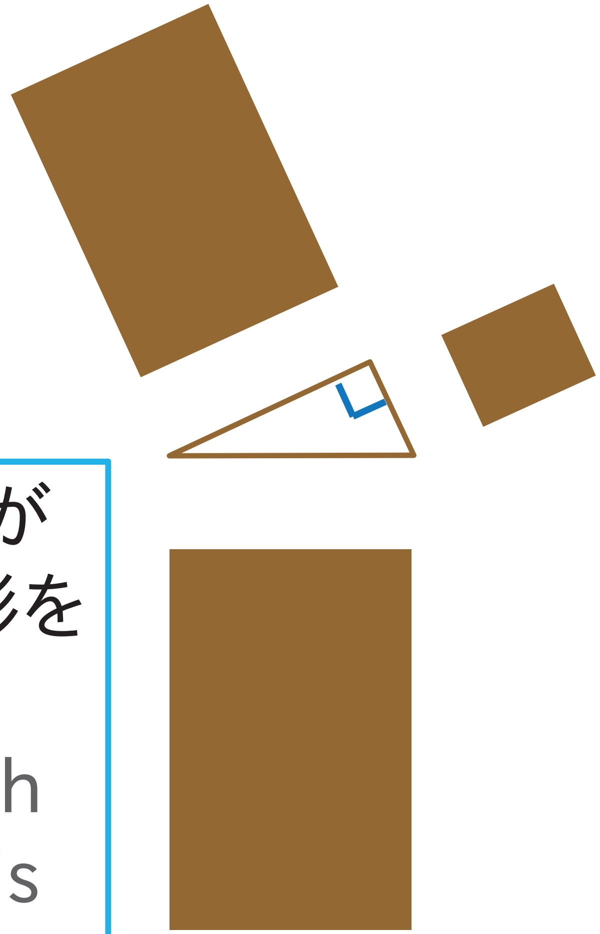
ここでは枝の角度は関係ありません。Here I'm not talking about inclination of branches.

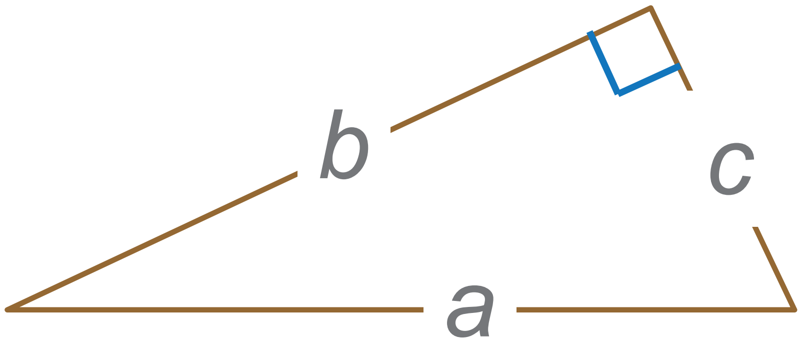


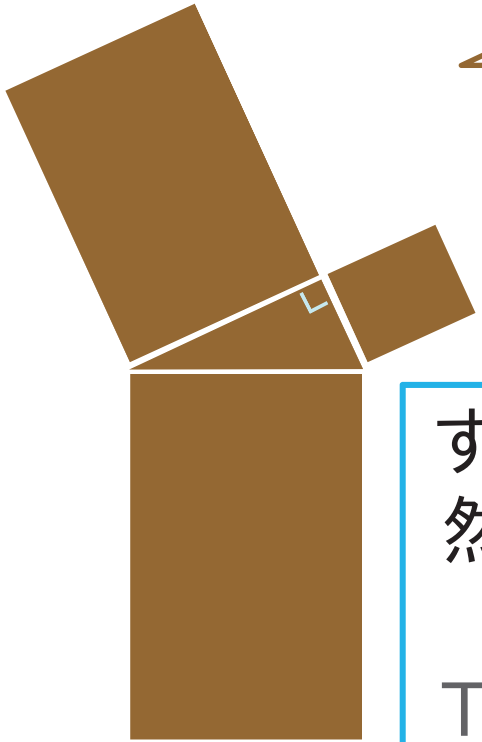


枝分かれ前の枝の太さ(a)が斜辺になるように直角三角形を描きます。

Draw a right triangle such that the hypotenuse (a) is the thickness of the stem before forking.

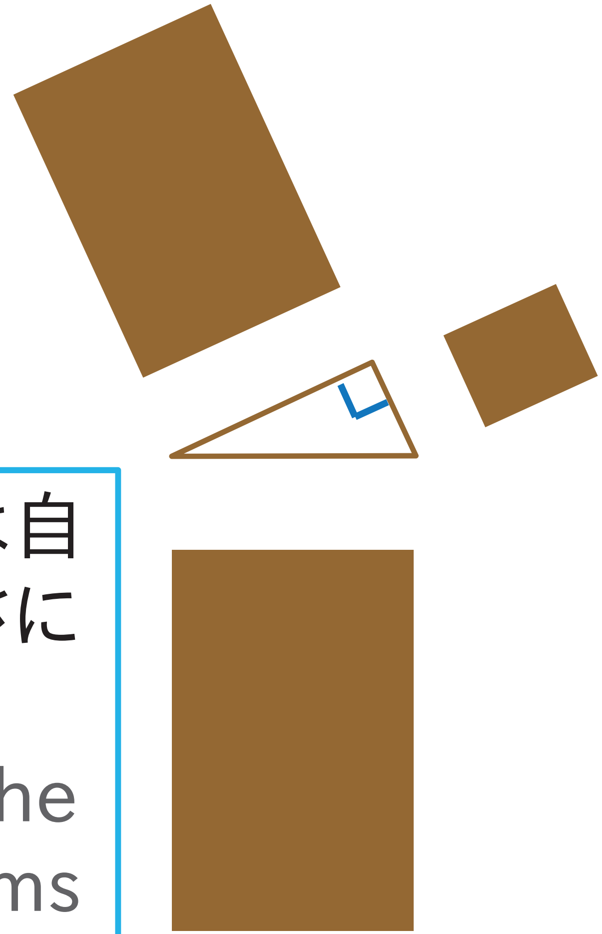


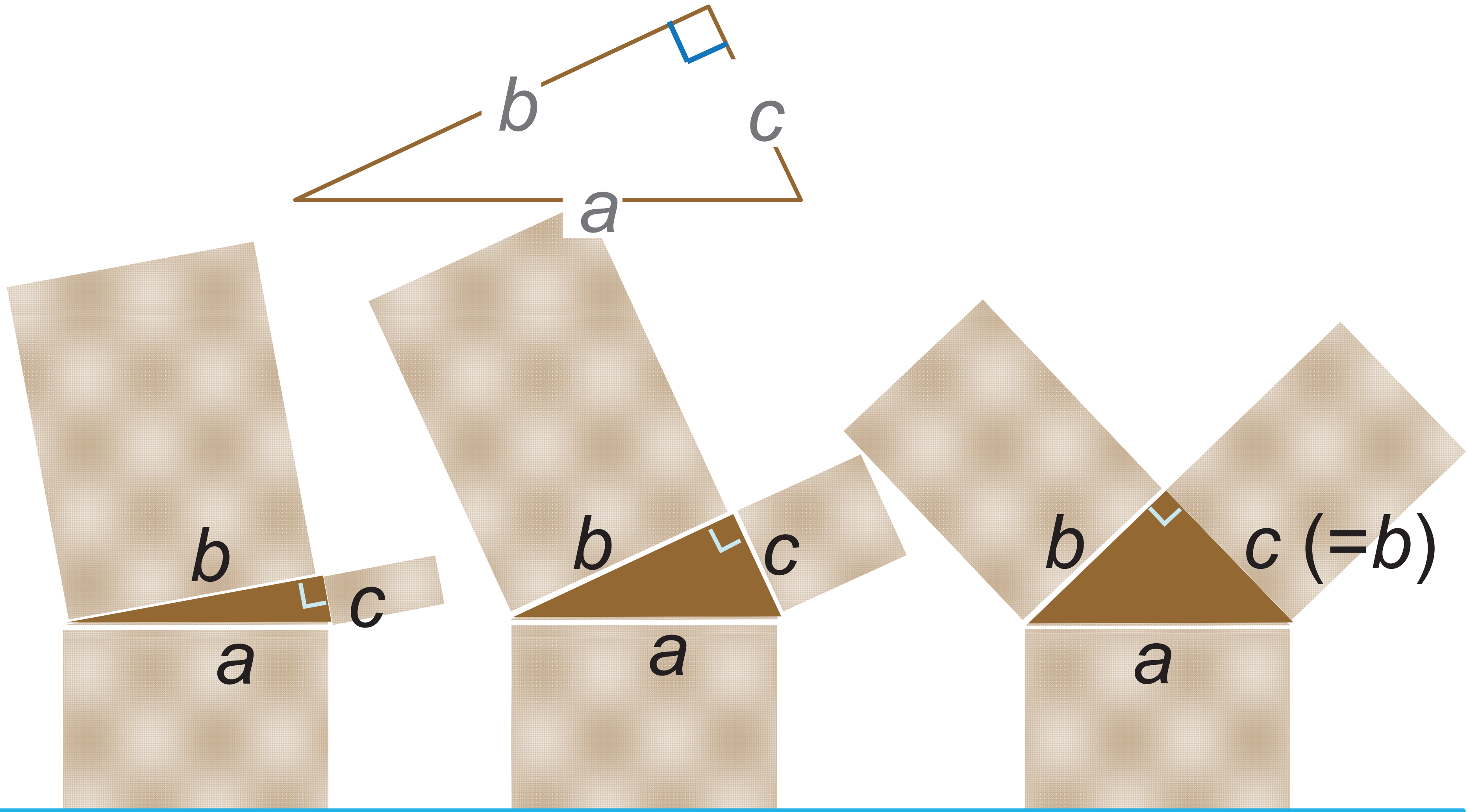




すると、のこりの2辺(b, c) は自然な枝分かれ後の枝の太さになります。

Then, length of each of the other two sides (b, c) forms natural branch thickness after forking.



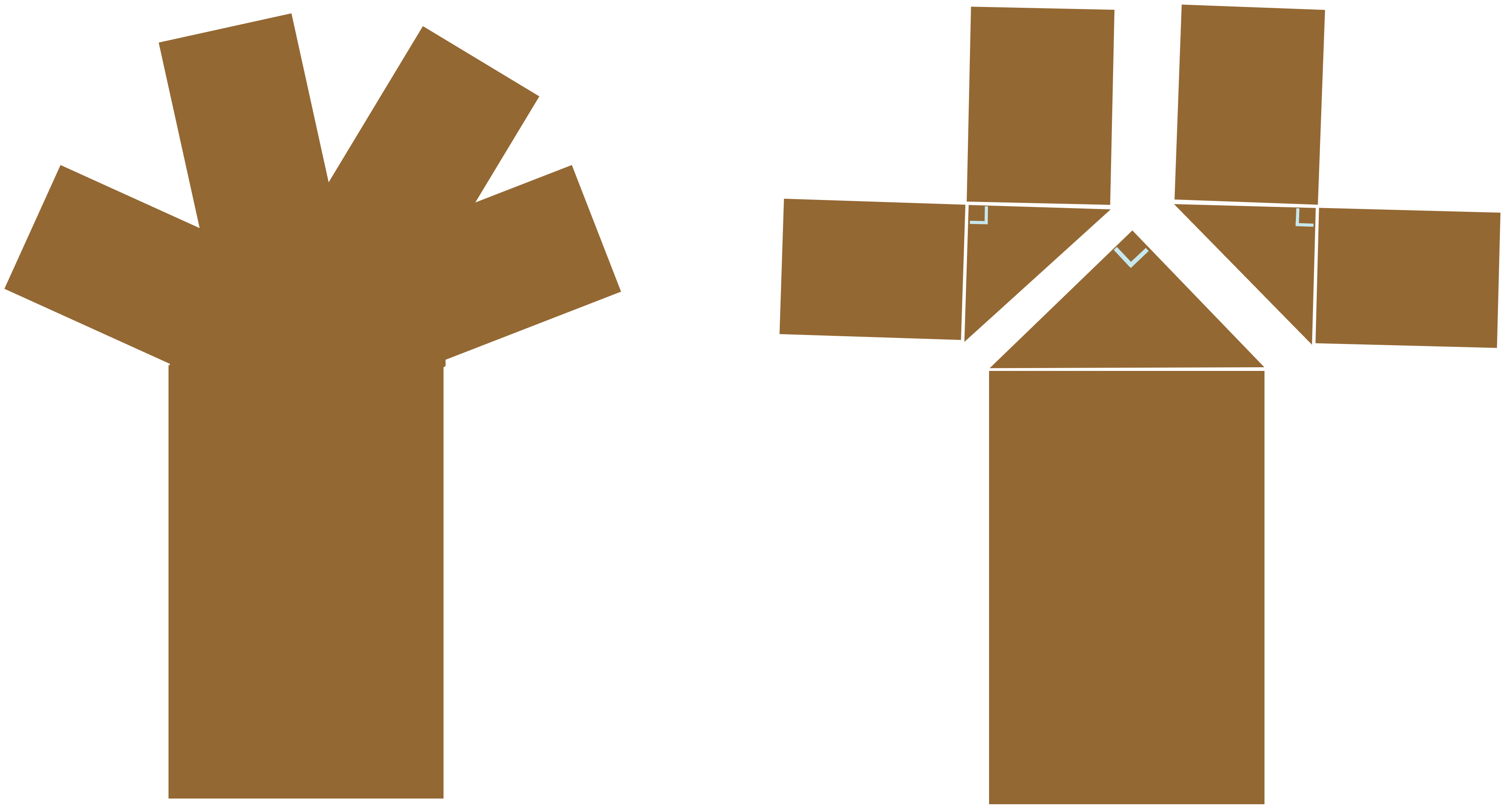


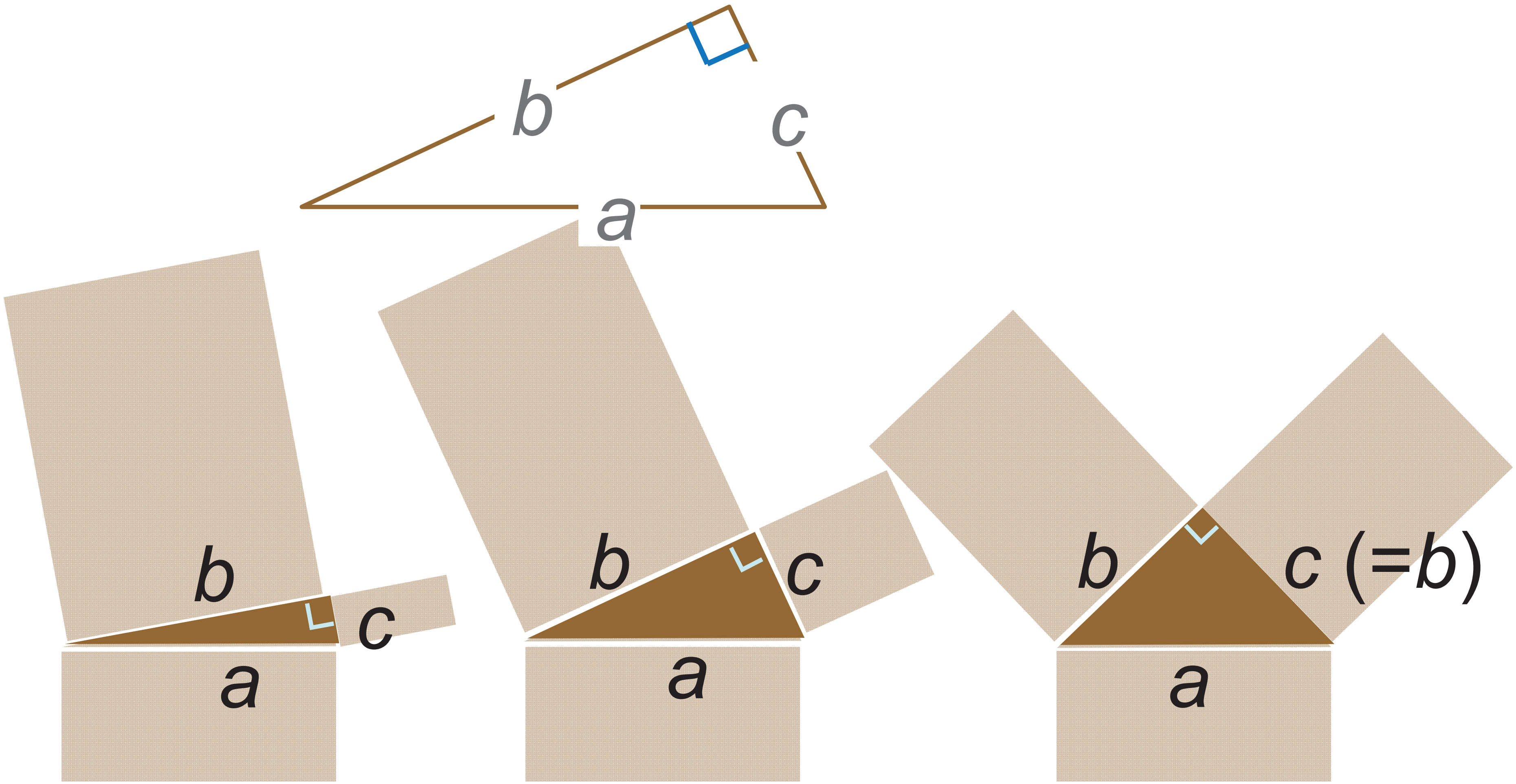
直角三角形の形を変えれば、いろいろな太さの枝分かれをつくれます。

Different patterns of branch thicknesses can be drawn by changing the shape of right triangle.

ここでは枝の角度は関係ありません。Here I'm not talking about inclination of branches.

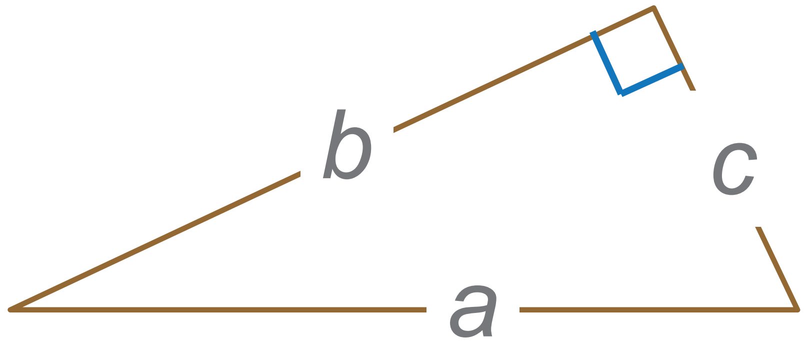
いちどにたくさん枝分かれするときもルールは同じです
The rule is the same for a multiple forking.

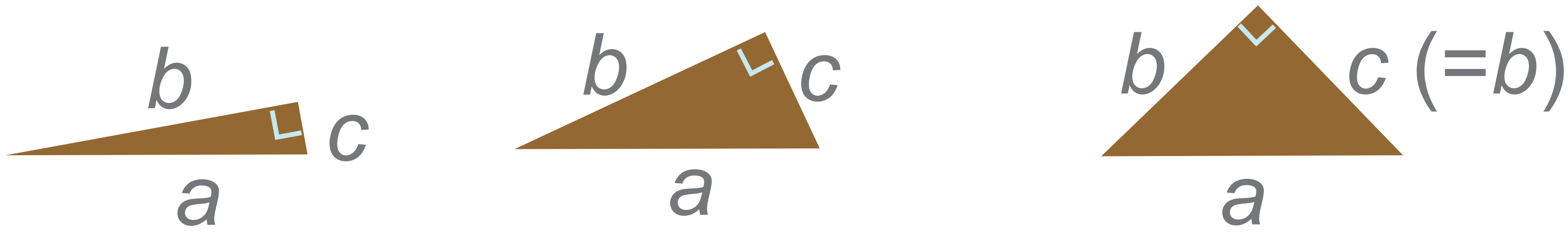




では、なぜ直角三角形で枝わかれ部の枝の太さを表せるのでしょう？

Why can a right triangle represent stem thicknesses in branch forking?





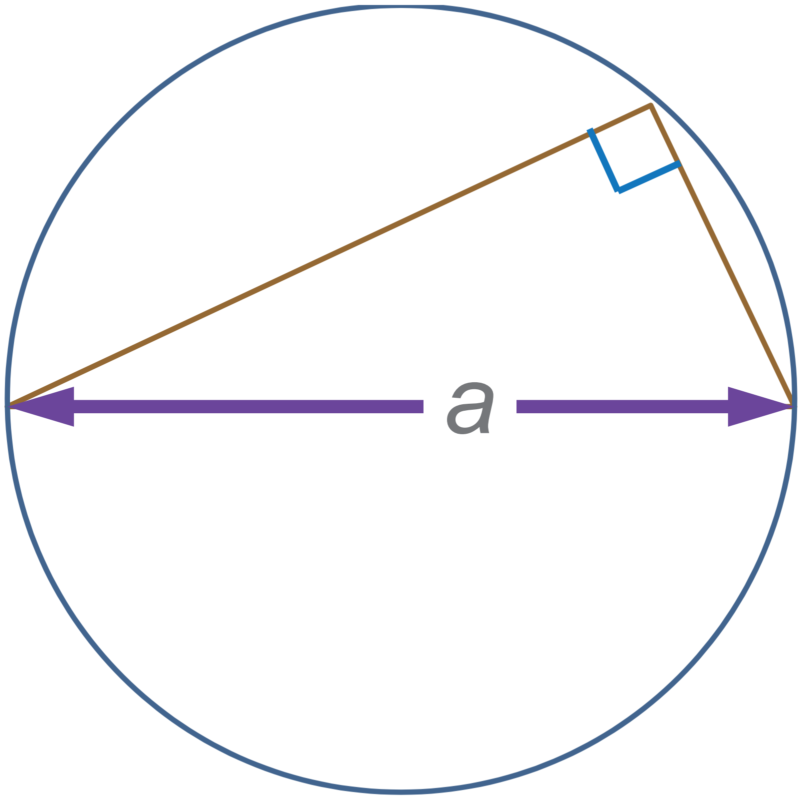
ヒントはこれ

Hints are this,

$$a^2 = b^2 + c^2$$

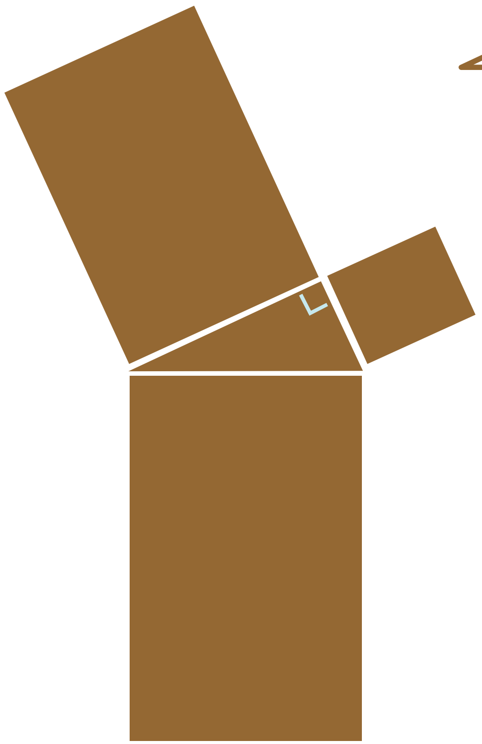
ピタゴラスの定理

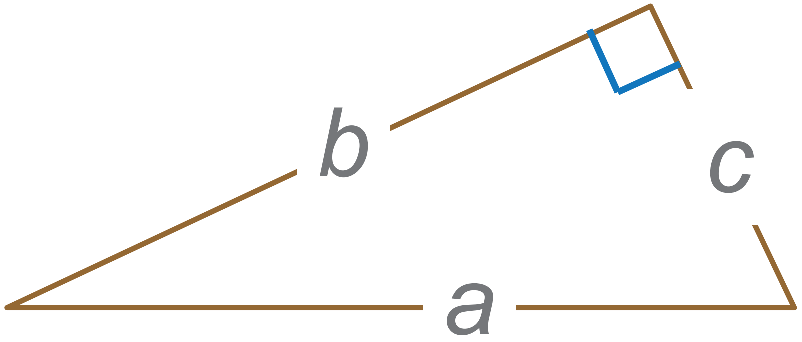
Pythagorean theorem

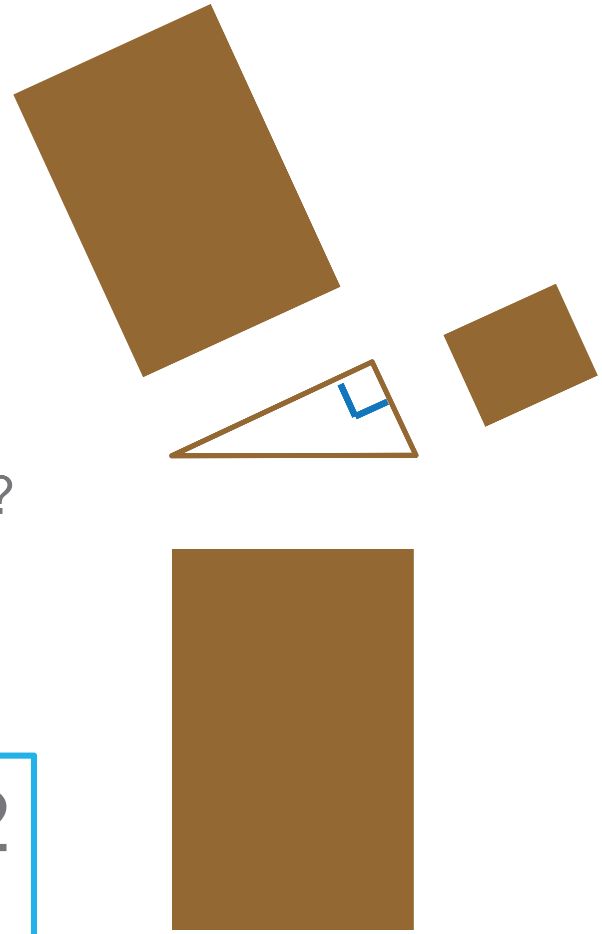


・・・とこれ
and this.

円の面積＝直径^2 ×π/4
Area of a circle = diameter^2 ×π/4
π＝3.1415・・・



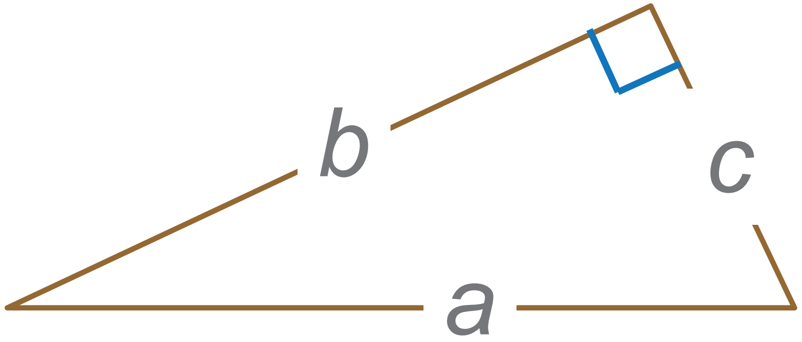


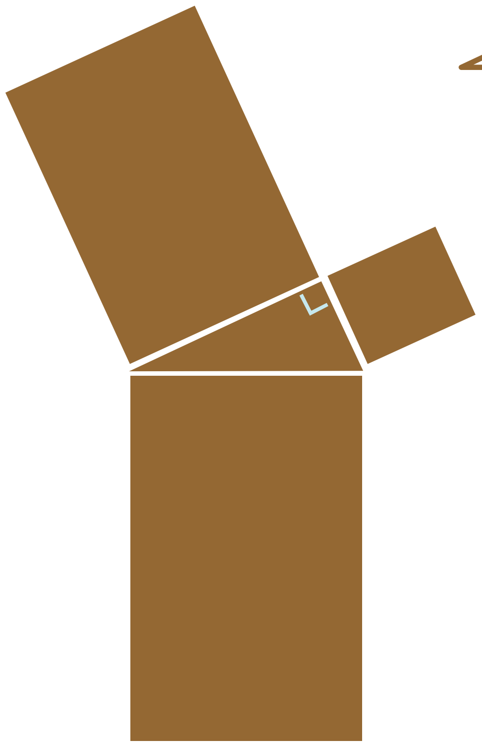


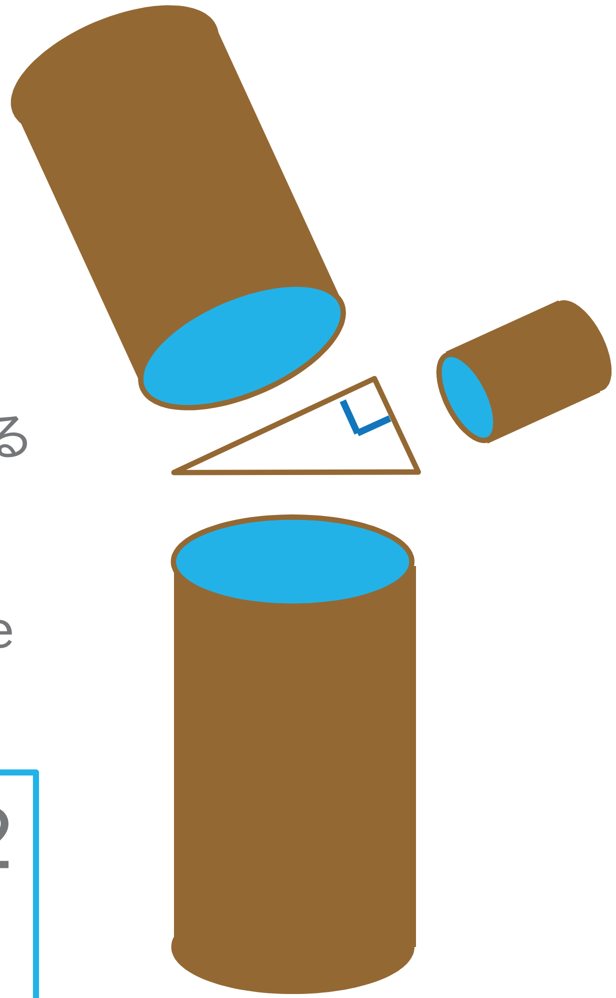
なんでピタゴラスの定理？
Why　Pythagorean theorem?

$$a^2 = b^2 + c^2$$

ピタゴラスの定理
Pythagorean theorem







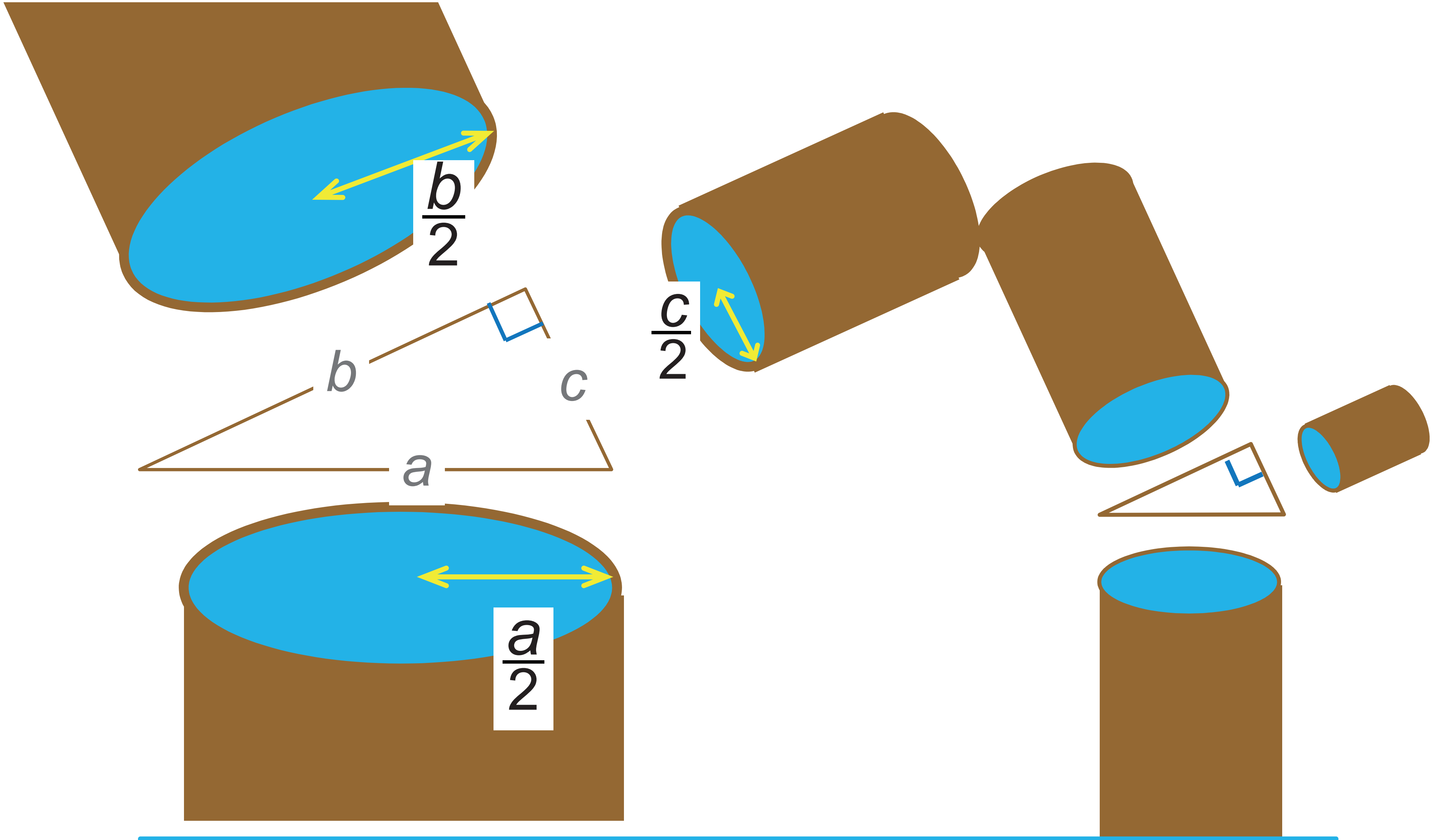
それは、幹・枝の断面積に関係してるから。

Because it has a relationship with cross-sectional area of the stem/branches.

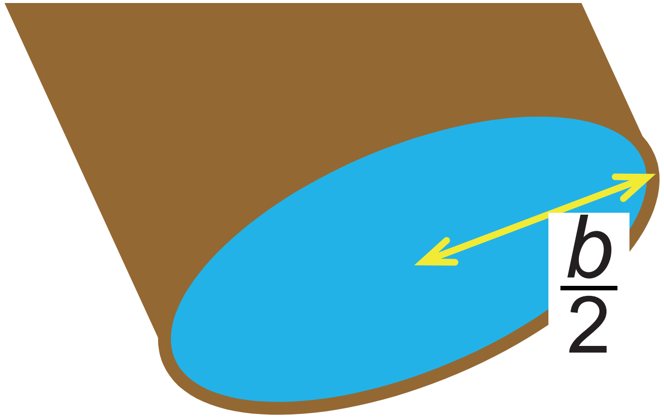
$$a^2 = b^2 + c^2$$

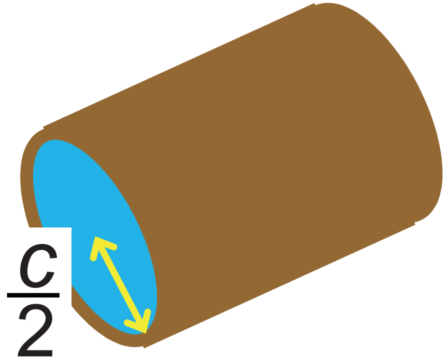
ピタゴラスの定理

Pythagorean theorem



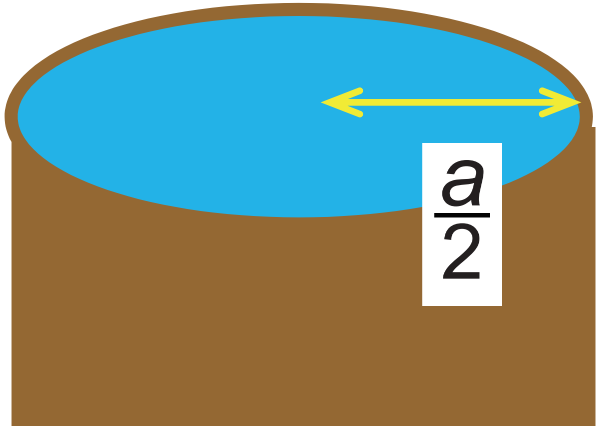
それぞれの幹・枝の断面積を半径から計算しよう
Let's calculate cross-sectional area for each.





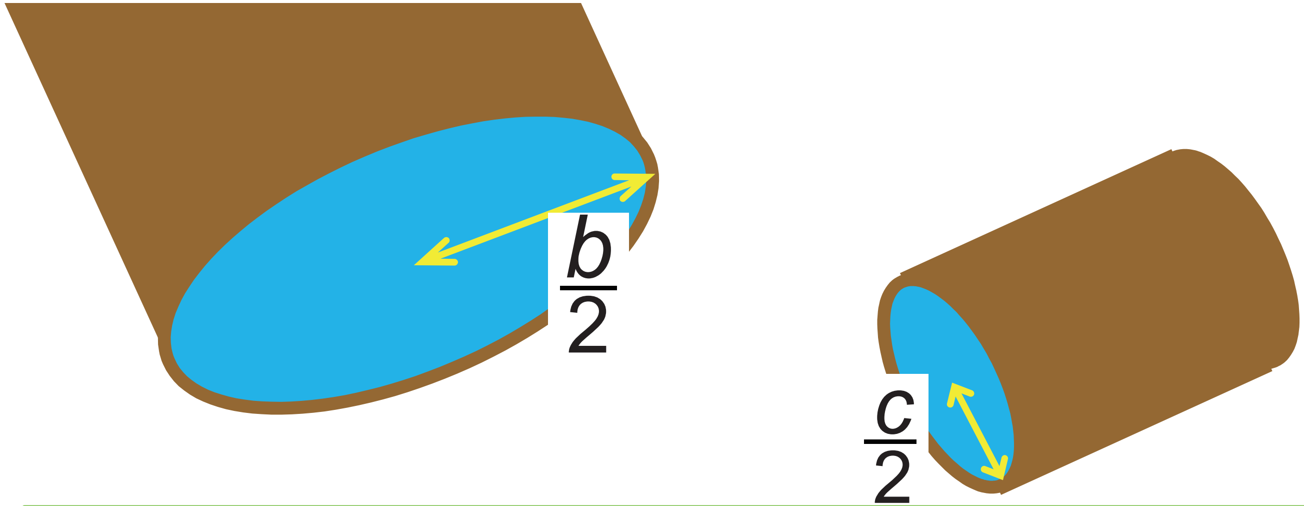
断面の面積＝$\boldsymbol{b^2} \times \pi/4$

断面の面積＝$\boldsymbol{c^2} \times \pi/4$

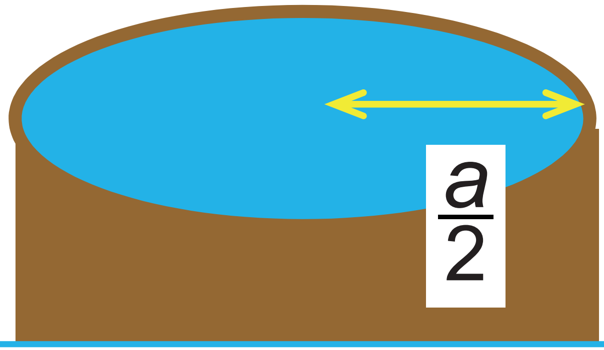


断面の面積＝$\boldsymbol{a^2} \times \pi/4$

それぞれの幹・枝の断面積を半径から計算しよう
Let's calculate cross-sectional area for each.



断面の面積＝$b^2 \times \pi/4$　　断面の面積＝$c^2 \times \pi/4$

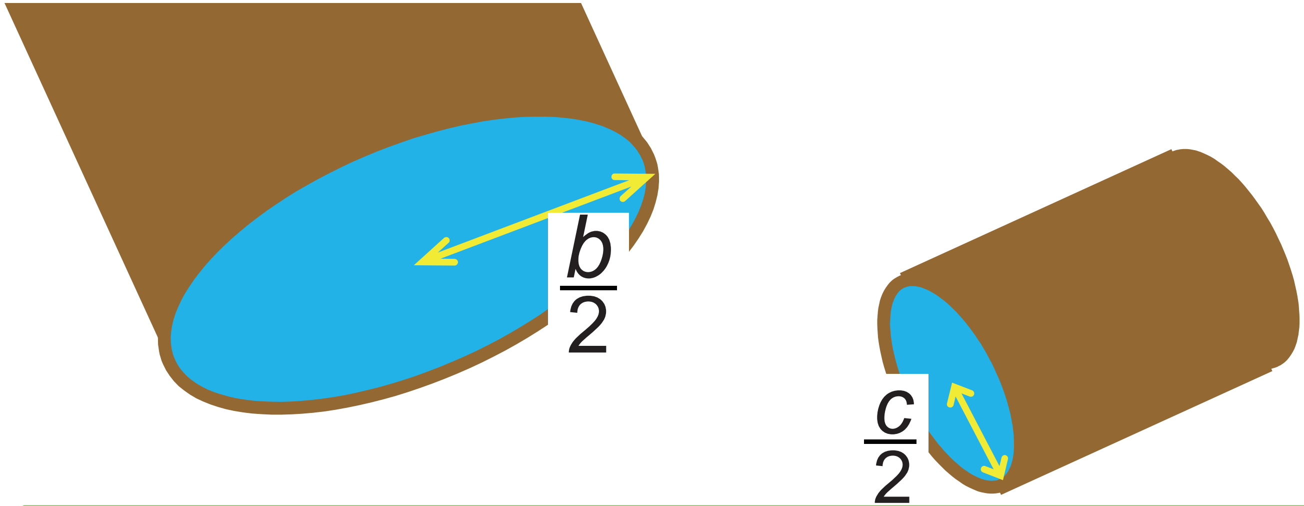


断面の面積＝$a^2 \times \pi/4$

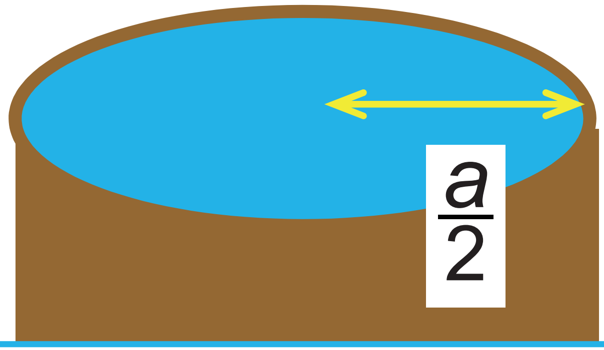
枝分かれ後の断面積の和は？

Sum of the cross-sectional areas after forking?

$(b^2 \times \pi/4) + (c^2 \times \pi/4) =$ ･･･



$b^2 \times \pi/4$ + $c^2 \times \pi/4$

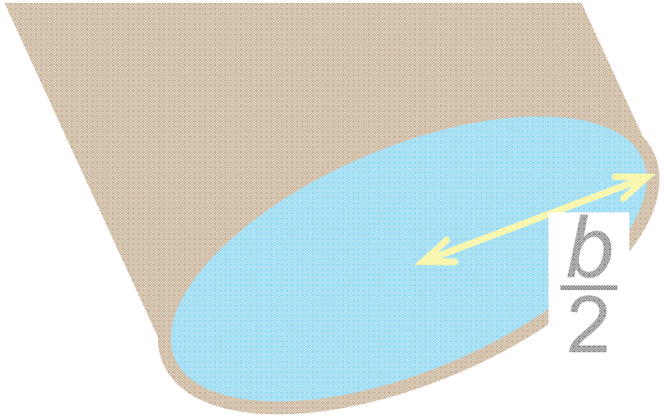


$a^2 \times \pi/4$

枝分かれ後の断面積の和は？

Sum of the cross-sectional areas after forking?

$(b^2 \times \pi/4) + (c^2 \times \pi/4) = (b^2 + c^2) \times \pi/4$

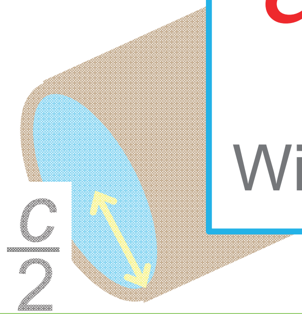


ピタゴラスの定理で

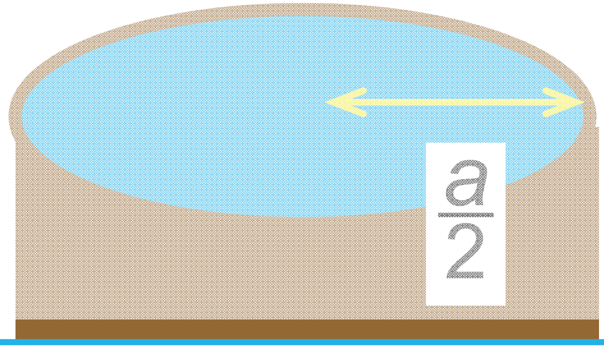
$$a^2 = b^2 + c^2$$

だったので‥

With Pythagorean theorem;



$b^2 \times \pi/4$ + $c^2 \times \pi/4$

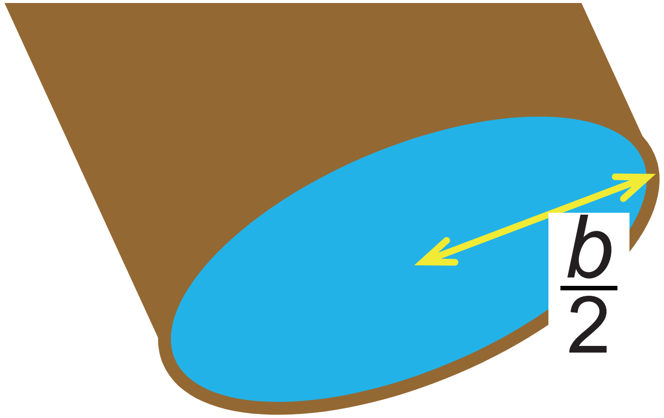


$a^2 \times \pi/4$

枝分かれ後の断面積の和は？

Sum of the cross-sectional areas after forking?

$$(b^2 \times \pi/4) + (c^2 \times \pi/4) = (b^2 + c^2) \times \pi/4$$

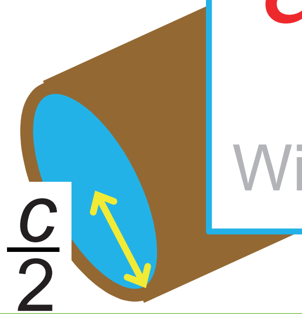


ピタゴラスの定理で

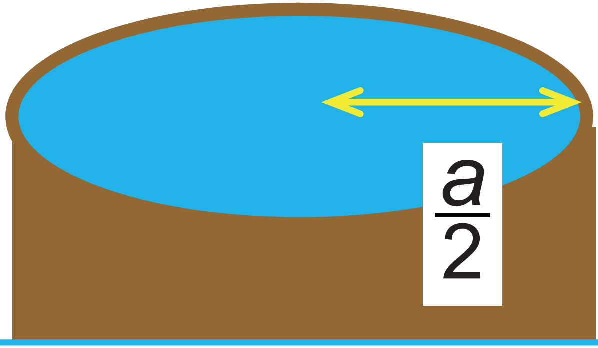
$$a^2 = b^2 + c^2$$

だったので・・

With Pythagorean theorem;



$b^2 \times \pi/4$ + $c^2 \times \pi/4$

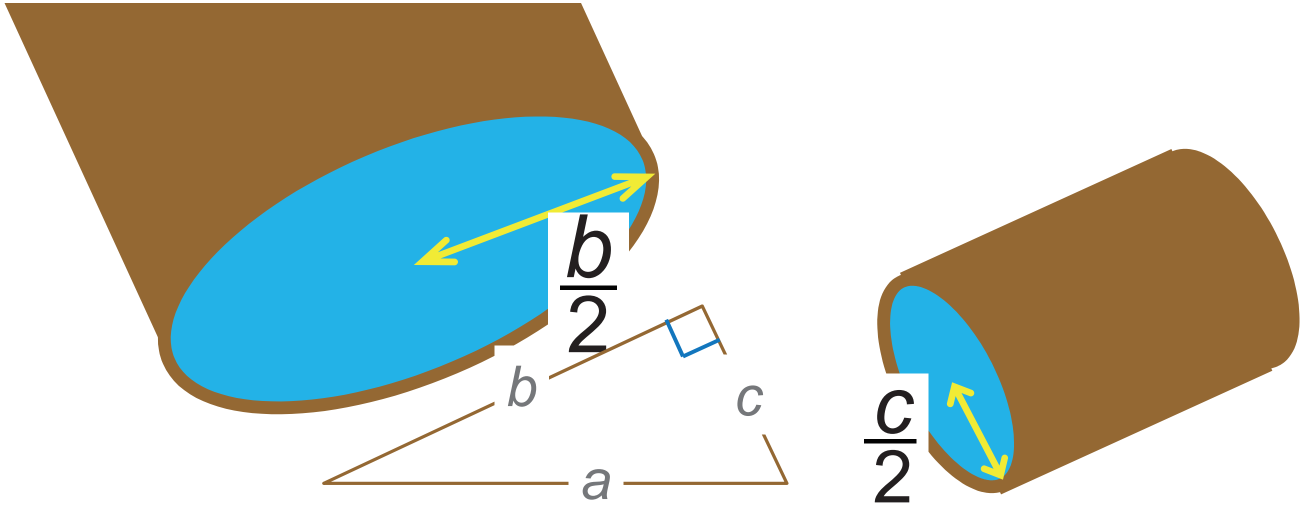


$= a^2 \times \pi/4$

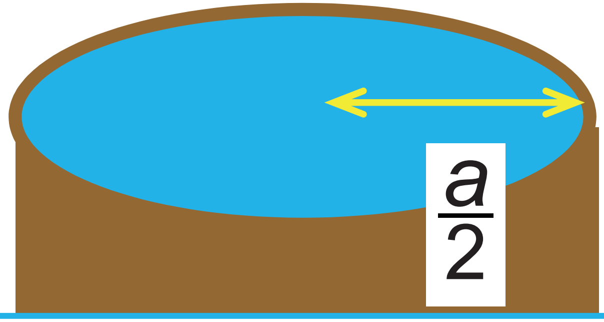
枝分かれ後の断面積の和は？

Sum of the cross-sectional areas after forking?

$$(b^2 \times \pi/4) + (c^2 \times \pi/4) = (b^2 + c^2) \times \pi/4 = a^2 \times \pi/4$$

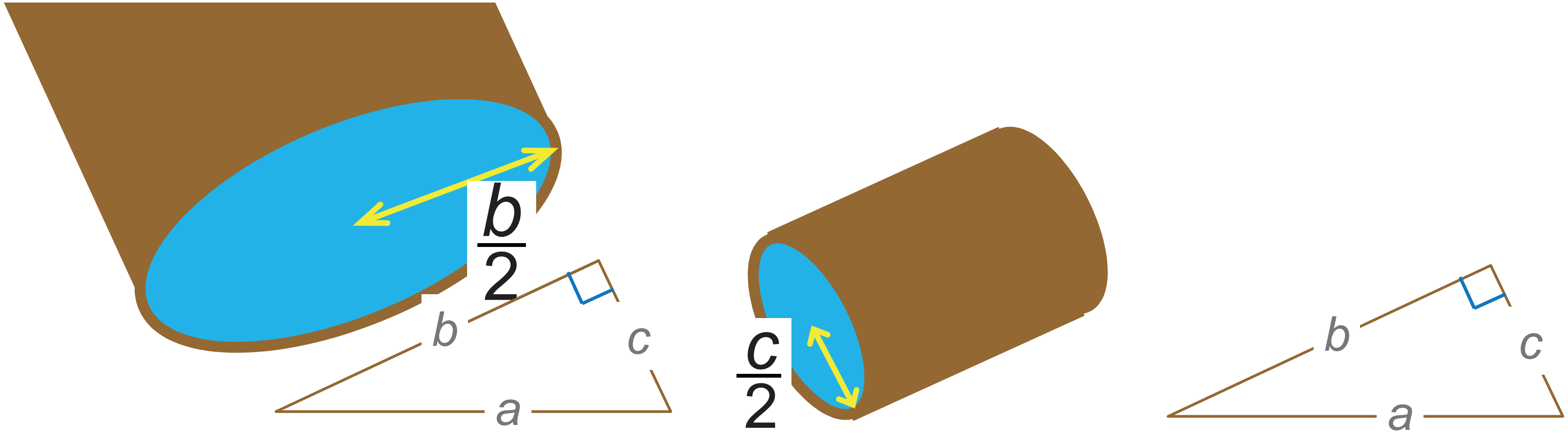


$$b^2 \times \pi/4 + c^2 \times \pi/4 = a^2 \times \pi/4$$



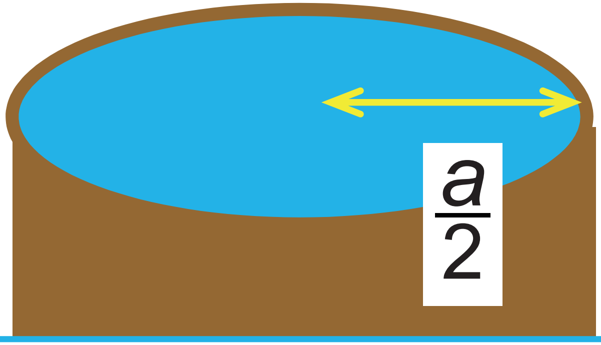
枝分かれ**後**の断面積の和は
枝分かれ前の断面積とおなじ

Sum of the cross-sectional areas **after** forking is equal to the cross-sectional area **before** forking.



$$b^2 \times \pi/4 \quad + \quad c^2 \times \pi/4 \; = \; a^2 \times \pi/4$$

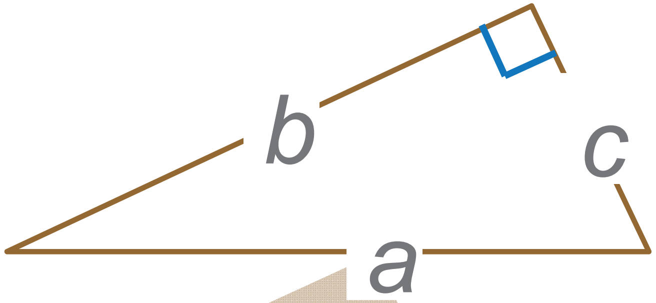
$$b^2 + c^2 = a^2$$



断面積どうしの関係はたまたまピタゴラスの定理と同じ式だった。

$$b^2 + c^2 = a^2$$

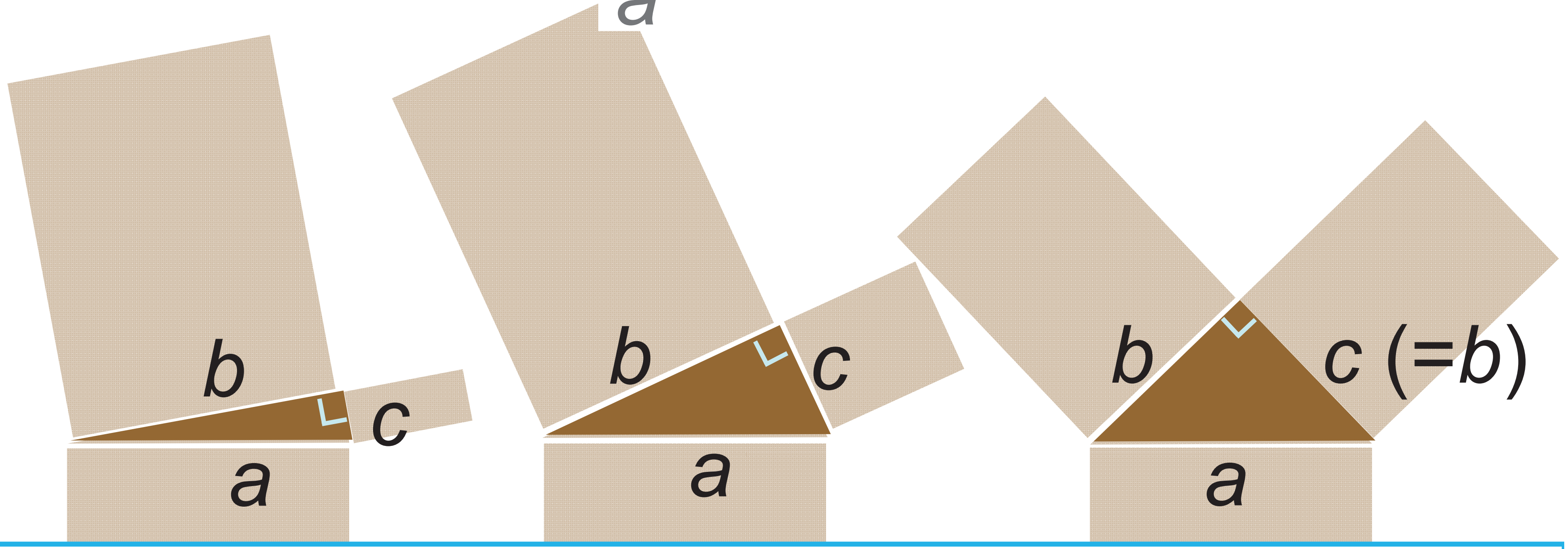
Relationship between cross-sectional areas happened to be the same as Pythagorean theorem.



$a^2 = b^2 + c^2$

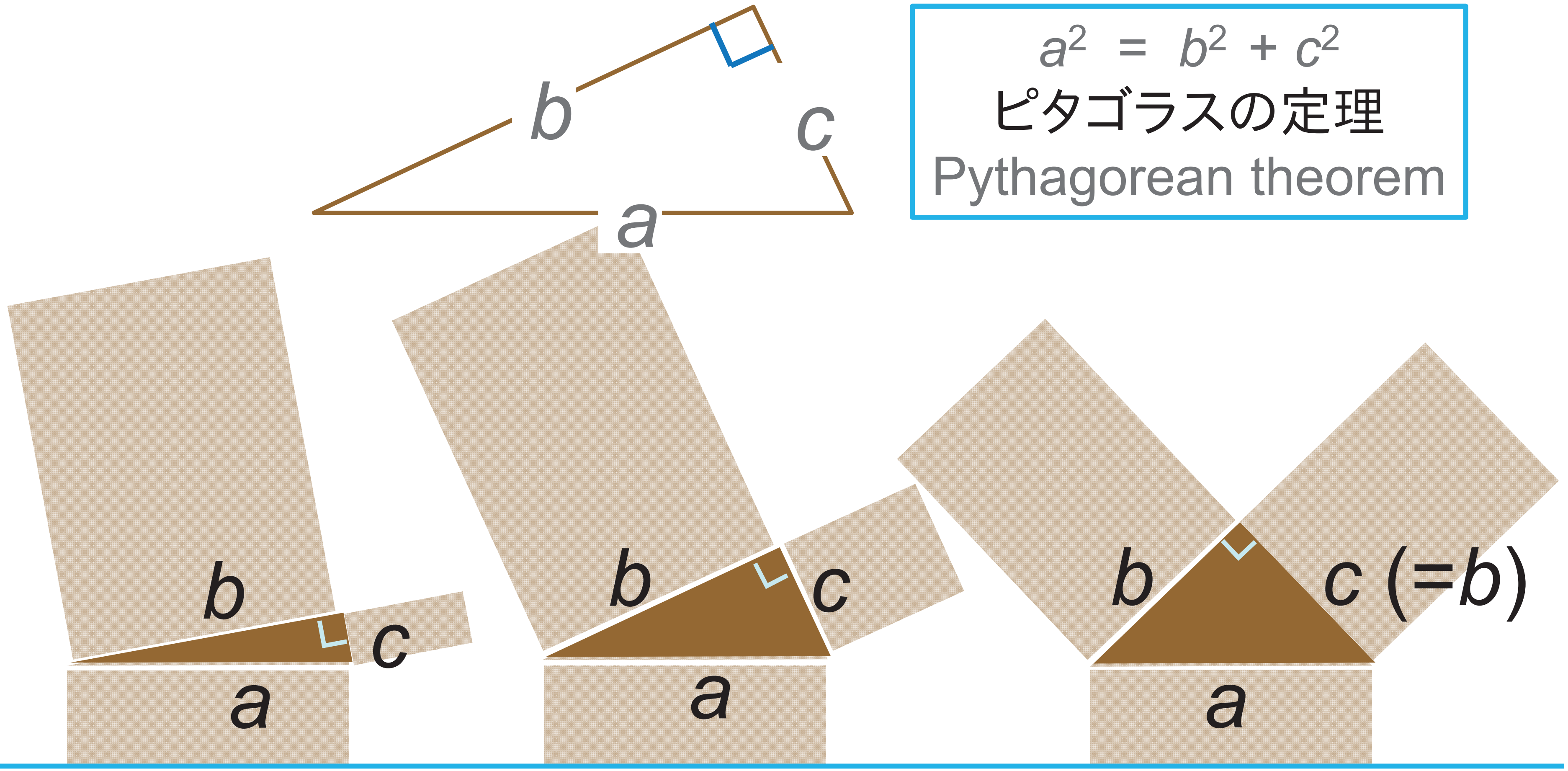
ピタゴラスの定理

Pythagorean theorem



（直角の）三角定規ではピタゴラスの定理が成りたっているので、三角定規の辺の長さを枝分かれ前後の幹・枝の太さにできる。

Three sides of a triangle (with a right angle) always satisfy Pythagorean theorem. So, lengths of the three sides can represent stem/branch thicknesses before and after forking.

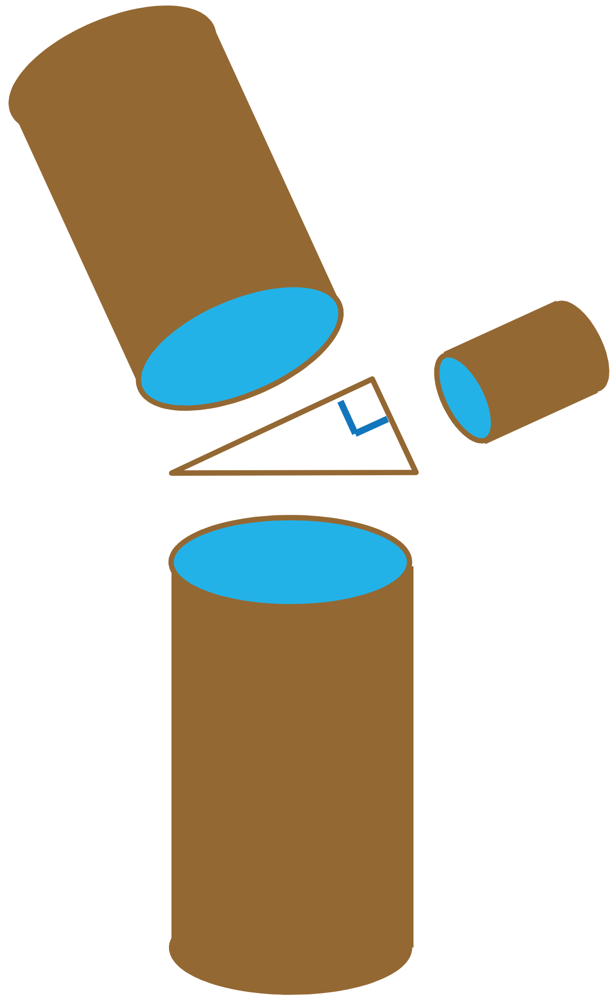


だから枝分かれ前の枝の太さが斜辺になるように直角三角形を描くと、
のこりの2辺は自動的に枝分かれ後の枝の太さになる。

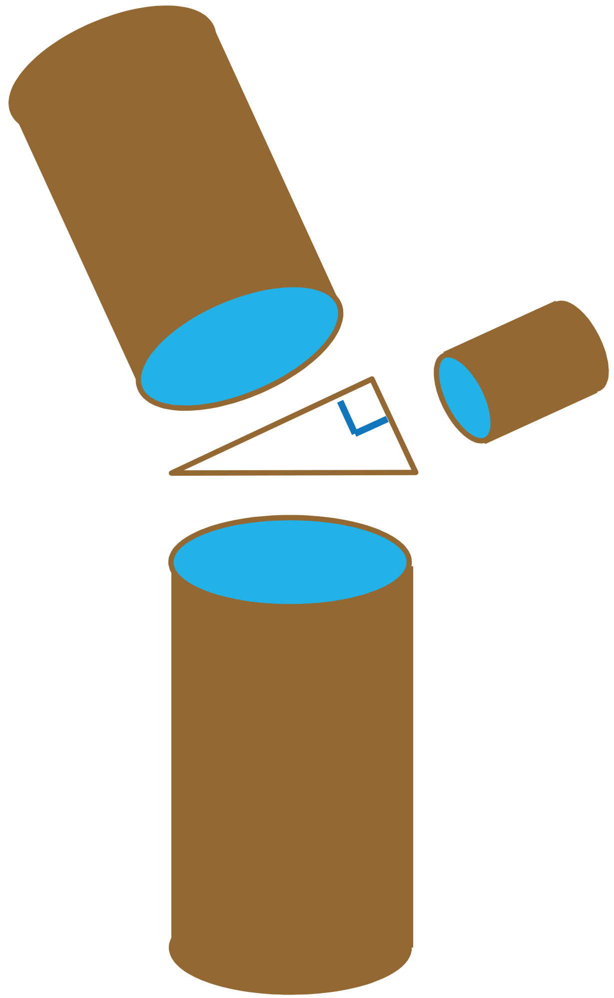
This is why drawing a right triangle such that the hypotenuse is the thickness of the stem before forking makes length of each of the other two sides be the branch thickness after forking.

なんで断面積が保たれるように枝分かれするのか、って？

Do you want to know why branches fork by keeping total cross-sectional area?



それを説明するには「光合成」の説明が必要です。
また別のところで。
We need to know a little about ”photosynthesis” to understand it. See you for now.



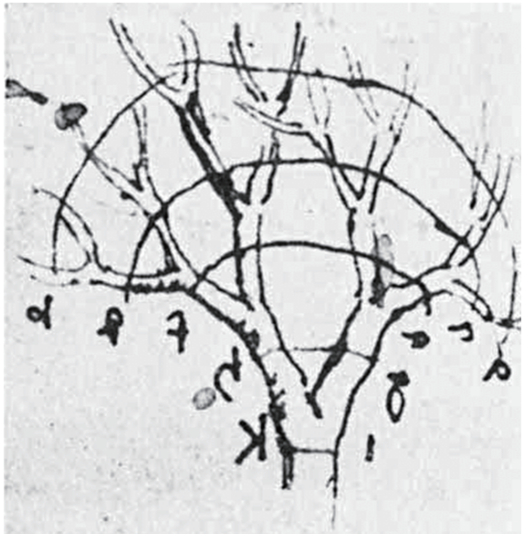
References: 参考文献

Shinozaki et al. (1964a) A quantitative analysis of plant form - the pipe model theory I. Basic analysis. Japanese Journal of Ecology 14(3), 97-105.
(Free link to the paper) http://ci.nii.ac.jp/naid/110001881211/en

Shinozaki et al. (1964b) A quantitative analysis of plant form - the pipe model theory II. Further evidence of the theory and its application in forest ecology. Japanese Journal of Ecology 14(4), 133-139.
(Free link to the paper) http://ci.nii.ac.jp/naid/110001881234/en

Chiba (1991) Plant Form on the Pipe Model Theory. II. Quantitative Analysis of Ramification in Morphology. Ecological Research 6, 21-28.

Perttunen et al. (1996) LIGNUM: A tree model based on simple structural units. Annals of Botany 77, 87-98.



. . . and the finding of a rule of branch forking

by Leonardo da Vinci

あ、これも忘れずに。
Oh, don’t miss it.

ブルーノ　ムナーリ　著　「木をかこう」
須賀敦子　訳　至光社国際版絵本

Bruno Munari. *Drawing a tree*. (English- translated)
Amazon ↓
http://www.amazon.com/Bruno-Munari-Drawing-Workshop-Series/dp/8887942765

Original (Italian) :
Bruno Munari. (1977) *Disegnare un albero*