Let’s make origami models for the alveolar system

It is a great pity that computer models cannot be touched in your hands in reality. If you could make a real solid model by yourself, you would understand more clearly how it would be generated and how it would be moved. Origami, a Japanese traditional paper craft, is very useful because one can make and operate it by oneself. When you handle the Origami alveolar duct model with your hands, you can feel airflow generated by Origami motion on the palm.

(1) Copy of Origami sheets

Make hard copies Origami sheets in Pages 3 and 4 in slightly thick A4 paper sheets (0.12 – 0.15 mm in thickness). Fetal and adult alveolar duct models will be made from Pages 3 and 4, respectively. Cut out all pieces, and fold black and red lines outwards and inwards, respectively. Indeed, it is never easy to make an adult alveolar duct model. In order to understand the 4D structure of the alveolar system, it is helpful to understand its morphogenetic process. This is the reason why the fetal duct model is described.

Exactly saying, traditional Origami should be made of a square sheet without cutting or connecting by tape. However, since the essence of the Origami model is to express its motion as reversible changes of folding angles, it is adequate to call those models “Origami models”.

(2) Single alveolar model

Fig.1 indicates a single alveolar Origami model, nearly identical to the computer model. Use a large piece in Page 4 (shown in the left end in Fig.1). Connect neighboring edges of pin parts by cellophane tape, and a pink ring, corresponding to the alveolar mouth, is generated. When the alveolar mouth is fold up, the volume of the alveolus decreases, and finally the alveolar mouth is closed (right end in Fig.1).

Fig.1. Origami model for single alveolus

max. volume ← breathing → min. volume
(3) Fetal alveolar duct model

The fetal alveolar duct is a rugged duct without alveolar opening. The alveolar formation begins one month before birth at which new alveolar septa grow from ridges of rugged wall and form alveolar mouths. Two strings in Page 3 are corresponding to the unwrapped rugged duct. Two sets of two green squares correspond to convex parts in the fetal duct, and other parts of the strings correspond to concave parts in the fetal duct. The latter is equal to the subtraction of the sheet by the red part in Fig. 1. Connect edges by cellophane tape so as to arrange convex and concave parts and alternatively and connect ends of strings respectively, then the fetal duct model is accomplished as shown in the left in Fig. 2. This is a cubic column with deformed four walls. There is a void in the center of each wall. The duct volume can be changed by changing shape of the void. Of course, there are no such voids in the real fetal duct but duct walls are continues.

Fig.2. Origami model for alveolar duct unit
(left: fetal duct, center: adult normal duct, rt. Alveolar collapse)

(4) Adult alveolar duct model

The adult alveolar duct model is generated by adding alveolar mouths to the fetal duct model. However, it is extremely difficult to do so in reality. Instead, it is feasible to prepare the concave parts with alveolar mouths as printed in Page 4. Connect them to the convex parts, then the adult alveolar duct model is accomplished.

There are eight alveoli in the alveolar duct unit, however, only four concave parts have the alveolar mouths. Since the convex parts are surrounded by alveolar mouths belonging to concave parts, they look like to have their own mouths. Although they look similar to concave parts at TLC, they become parts of smooth duct wall when the alveolar mouths are closed.

There are a few slight differences between the Origami and the computer models: First, the alveolar mouth in the Origami model is not contracted but folded. However, when fold interval is very small, it behaves like a elastic membrane. Secondly, although all elements in the Origami model do not change their shapes, those in the computer model slightly do in order to connect to neighboring ducts at all directions without gap through respiratory cycle.
1. Cut out strings A and B.
2. Fold black lines inward, and fold red lines outward.
3. Connect edges having the same number each other by cellophane tapes (A1 and B1, A2 and B2, ...).
4. Connect edges at two ends in respective strings by cellophane tapes (α and α, β and β).
5. Connect vertices having the same letters (p and p, q and q,...).
Origami model for mature alveolar duct

1. Cut out all parts, and fold lines.
2. Connect edges in red parts, and make four large alveoli.
3. Connect large alveoli and small alveoli (= set of two squares) alternatively, and make two strings.
4. Connect edges in two strings in the same way for the primitive duct.

Harder these parts, the better for motion.