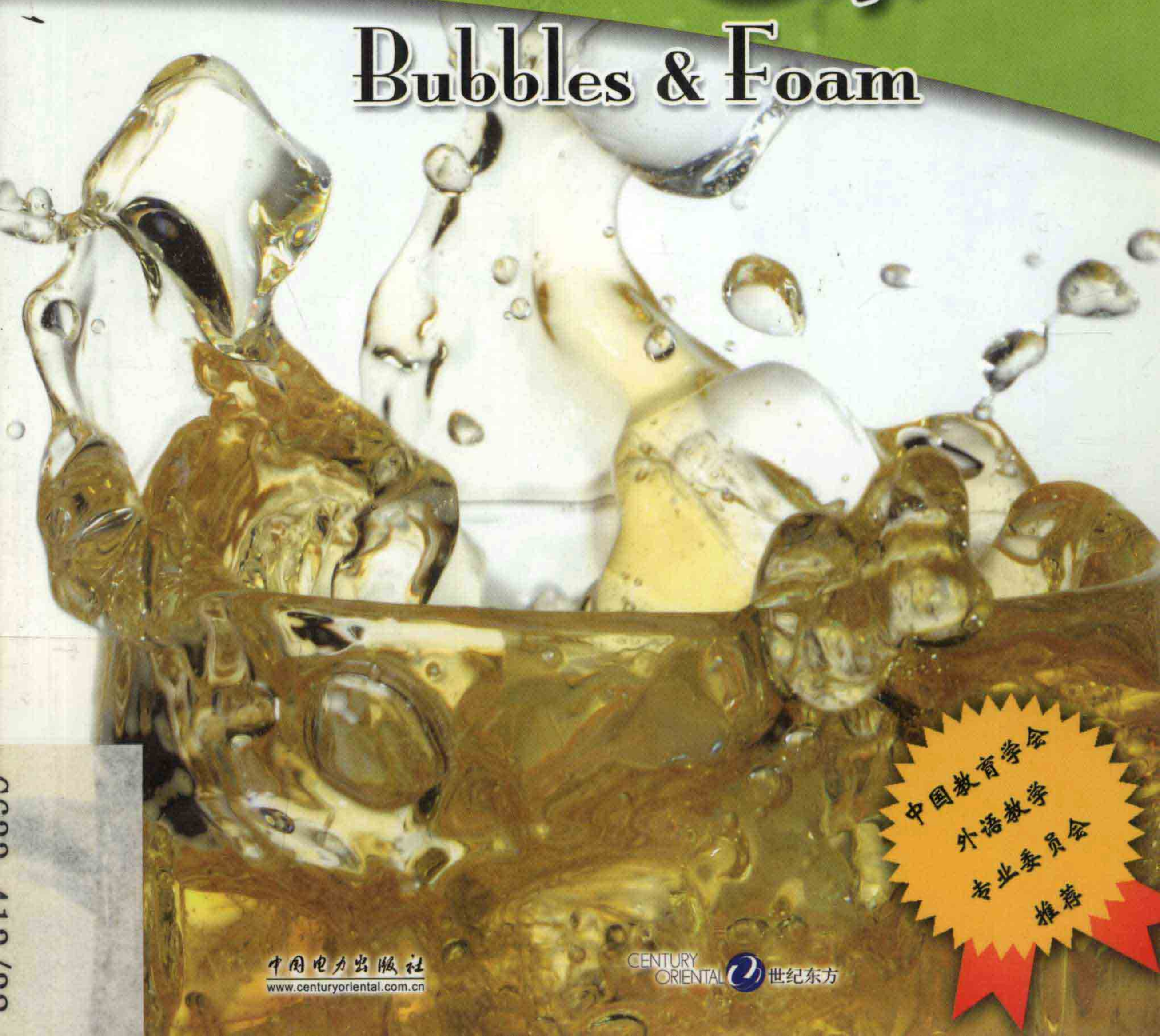
阅读空间 · 英汉双语主题阅读

气泡与泡沫

Bubbles & Foam



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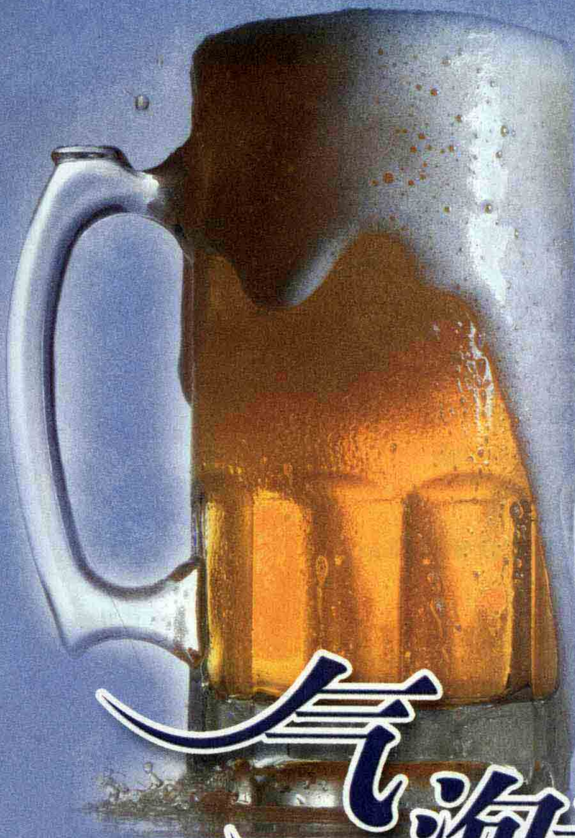

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强 云 译

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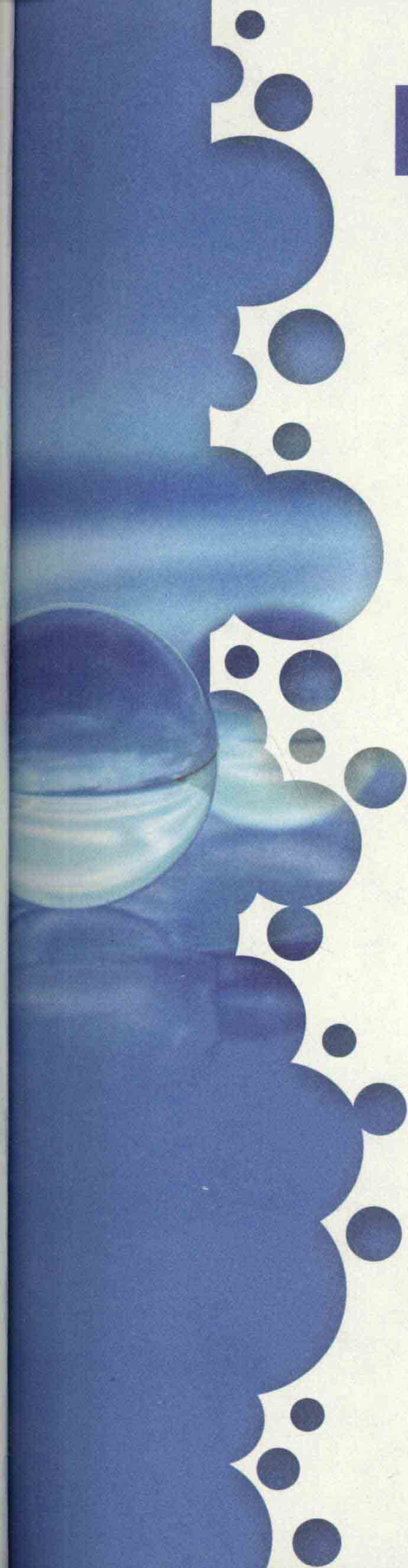

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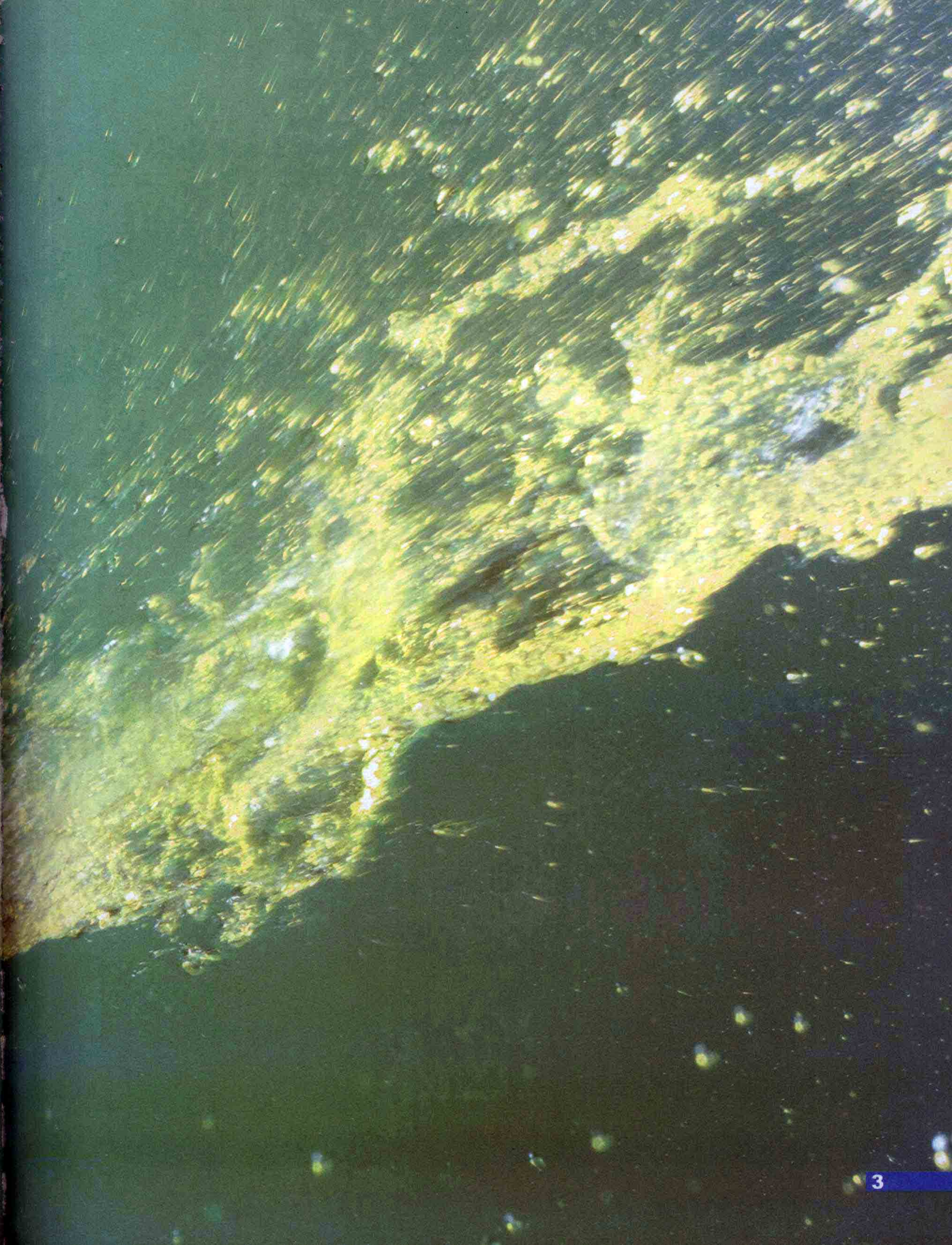
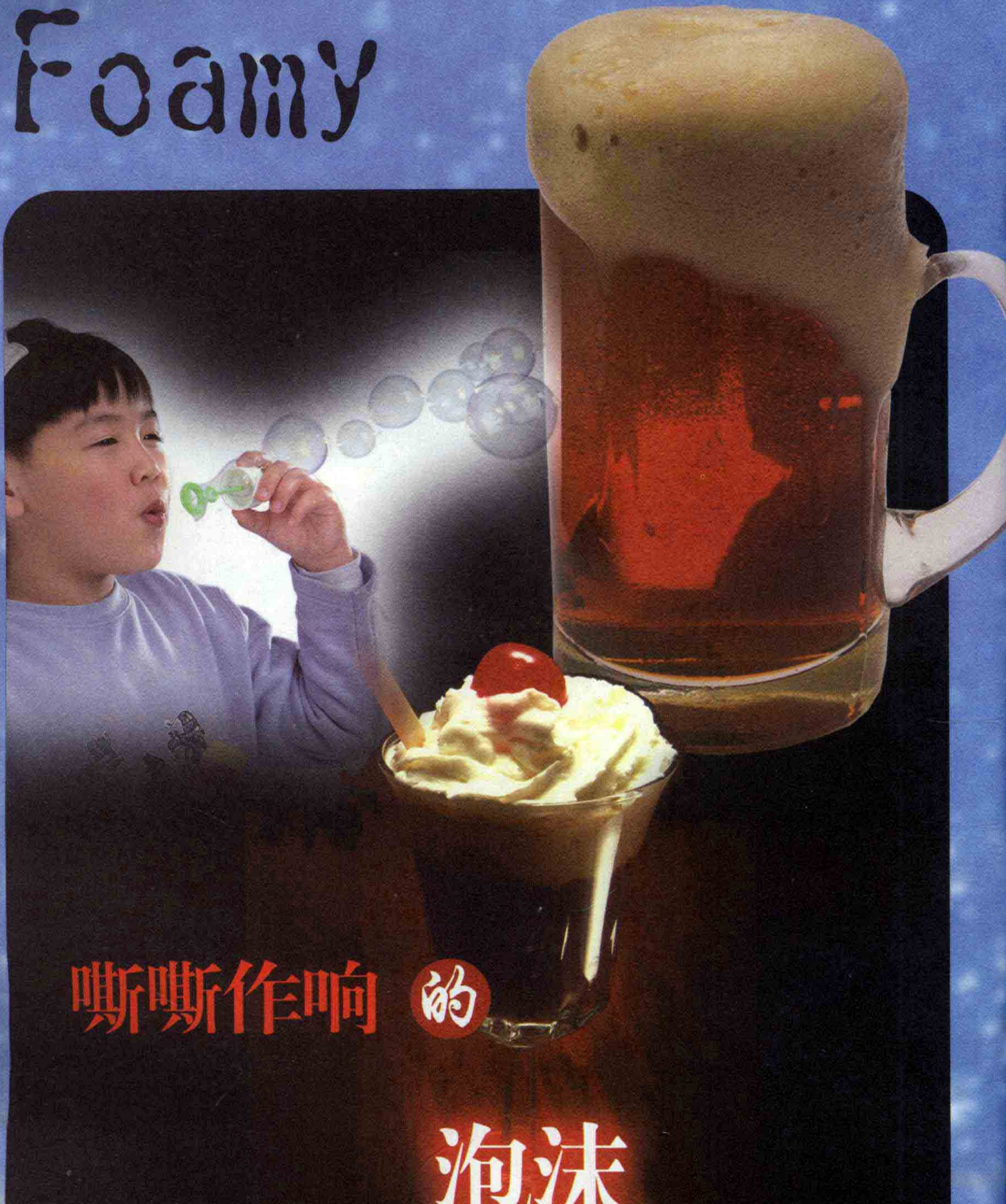
Editor's Message 编辑手记

如果有人告诉你他们的职业是研究气泡和泡沫，开始你也许会笑。但是科学家确实研究气泡。尽管说起气泡通常都会联想到娱乐，实际上气泡对我们生活中和自然界的许多事物都是很重要的，从制药业到环保上的温室效应。有流体的地方——海洋、汽车油箱和血液中——都有气泡。当然，我们也可以用草棍人工制造气泡。气泡堆积起来，就会变成诸如好吃的奶油那样的泡沫。当然有些泡沫也会带来麻烦。本书将告诉你很多你不知道的关于气泡和泡沫的有趣事情。读吧，没准儿你就成为一名气泡学家或泡沫学家！



Foamy



嘶嘶作响的泡沫

"Fizzicks"

by Sidney Perkowitz

Thick and gooey whipped cream topping on a banana split. Sweet foamy root beer spilling over a cool frosted glass. Refreshing bubbles sparkling in a tall tumbler of soda pop. What would we do without bubbles and foam? From blowing bubbles to the pleasures of fizzy soft drinks and fluffy soufflés, bubbles and foam are fun. Although they convey a lightness of spirit, bubbles and foam are not light in the science they contain. As you'll see in this book, the study of bubbles and foam touches on physics, mathematics, biology, chemistry, earth science, and cosmology. Foam is also widespread in technology and manufacturing, from specially tailored medical drugs to foamed aluminum. Are you ready to learn some foam "fizzicks" and have some fun?

BUBBLES AND FOAM EVERYWHERE

Defined as bubbles or cells of gas spread throughout a liquid or a solid, foams are surprisingly common in nature and in our lives. From soapsuds in the shower to sea foam at the beach, from shaving cream on a wet face to the meringue on lemon pie, foams are all around us. Solid foamy structures such as bread or cake might be less apparent foams, but they are still foams. Slice a nice thick piece of angel food cake or dark rye bread and you will see the voids left after carbon dioxide has escaped. Cork and sponge, which gain resilience and floatability from a multitude of tiny air-filled cells, are also foams. They are made up of dead biological cells, but the living cells that make up our bodily tissues and organs also behave somewhat like a foam.

Other natural foamlike structures include pumice,

冰淇淋香蕉条上覆着厚厚的、黏黏的奶油；覆着冷霜的玻璃杯中溢出甜滋滋、泛着泡沫的根汁饮料（用植物根茎调味的不含酒精的饮料——译着注）；高脚杯里苏打汽水冒着清新的气泡。没有了气泡和泡沫，我们能做什么？无论是吹泡泡还是享受汽水和松软的蛋奶酥，气泡和泡沫都给我们带来乐趣。尽管它们是轻盈的化身，其中却蕴涵了深刻的科学原理。在本书中，你将会了解到气泡和泡沫的研究涉及物理、数学、生物、化学、地球科学和宇宙学等众多学科。此外，从特制药到泡沫铝，泡沫还广泛应用于技术和生产领域。你准备好要一边学习一些关于泡沫的知识，一边享受快乐了吗？

无处不在的气泡和泡沫

泡沫是指分散在液体或固体中的气泡或气体细胞，在自然界和我们的日常生活中十分常见。洗澡时的肥皂沫，海滩上的海水泡沫，潮湿的脸上的刮胡膏，柠檬派上的酥皮，泡沫无处不在。而诸如面包、蛋糕这些看似不很明显的固体泡沫结构实则也是泡沫。切下一块白蛋糕或一片黑麦面包，你就可以看到二氧化碳挥发后留下的空隙。木塞和海绵亦是如此，大量充满空气的微小细胞使其具备弹性和浮力。虽然木塞和海绵是由死去的生物细胞构成的，但构成我们人体组织和器官的活细胞的性状也和泡沫类似。

自然界还存在着其他一些类似泡沫的结构，如浮石这种火山喷发时形成的多孔

the airy rock made in volcanic eruptions that is light enough to float (see "Lava Bubbles: Small and Big"). Even the awe-inspiring cosmic geometry of the universe has a foamlike structure. The galaxies are arranged in space so as to form the surfaces of immense bubbles hundreds of millions of light-years across!

Look around you. How many foams can you identify?

FROM A BUBBLE TO A FOAM

Foam requires more than pure liquid and pure gas to form. Water molecules tend to pull together in an effect called *surface tension*, which makes drops and bubbles. This surface tension alone, however, is not sufficient to make a long-lasting foam. Something must be added, the molecules of which interact with the water to make bubble walls stretchier, and therefore longer-lasting. Such an additive is called a *surfactant*, short for "surface-active agent." Surfactants make water more elastic and able to form sturdy bubbles and foam.

To see this for yourself, fill a clear plastic bottle half full of water, and shake it vigorously. A multitude of bubbles forms but disappears as soon as you stop shaking. Now add a drop or two of ordinary liquid soap, and shake the bottle. When you stop, it will be filled with a foam that will last for hours, although its form will change.

Isn't foam almost magical? It is so different from its ingredients. Air and water are clear, yet the foam is white and opaque; air and water flow freely, yet the foam flows sluggishly; neither air nor water sticks to your hand, yet the foam clings even to the bottom of your overturned hand.

岩石，轻得足以飘浮在水中（参见《大大小小的熔岩气泡》一文）。即便是令人敬畏的宇宙几何天体中亦有类似泡沫的结构。太空中各星系有序排列，以形成一个个相距上亿光年的巨型气泡的表面。

看看你的周围，你能找出多少种泡沫？

从气泡到泡沫

泡沫的形成不仅仅需要纯液体和纯气体。水分子结合在一起形成表面张力，进而形成水滴和气泡。但表面张力本身不足以长时间维持泡沫，必须添加一些别的东西与水相互作用，使气泡壁更具韧性，也更持久。这种添加物称为表面活性剂。它能增加水的弹性，从而形成坚实的气泡和泡沫。

你可以自己尝试一下。往一个干净的塑料瓶中装入半瓶水，使劲摇晃，就会产生大量的气泡，但你一停止摇晃，气泡就会随之消失。这时加入一两滴普通的肥皂液，再摇晃瓶子，等你停下来的时候，瓶中又会充满泡沫，并能保持几个小时，尽管泡沫的形态有所改变。

泡沫难道不神奇吗？它和构成它的成分物是如此的不同。空气和水是清冽的，而泡沫却是白色而不透明的；空气和水流动自如，而泡沫流动

Photo by Marilyn Fletcher

Adding a surfactant such as detergent to a bottle of water and shaking it makes a foam that will last for hours.

Photo by Marilyn Fletcher

THE PROPERTIES OF FOAM

Look at the foam in the bottle when it is first made (a magnifying glass may help). You will see a crowd of round bubbles separated by soapy water. But the water between the bubbles will soon drain under the pull of gravity. This drainage is one reason that foams do not last forever, for it thins the films between the bubbles until they are too weak to sustain themselves. (To better understand this death by gravity, researchers plan to study foam in the weightlessness of the International Space Station.)

As the films become thinner, the spherical bubbles crowd together until each becomes a soccer-ball-like structure, defined by flat or gently curving faces. The surfaces, however, are not all the same size as those on a soccer ball, but instead come in apparently random size and shape. The foam also "coarsens," meaning that the bubbles become bigger, and the bubble walls display rainbows of color (more on this later). Hours later, the foam is reduced to a few thin films. When the last of these expires, the bottle returns to its original state, half full of soapy water. All it takes to start the process over again, though, is a few good shakes.

WHY ARE BUBBLES ROUND?

Right after you reshake the bottle, use the magnifying glass to look closely at the isolated bubbles in the newly made foam. They are almost perfect spheres. This is because it takes surface energy to maintain a bubble, and like any physical system, a bubble is most stable at its lowest energy level. Lowest energy is achieved when

缓慢；空气和水无法粘到你的手上，而你把手掌翻过来，泡沫仍然可以紧紧粘在你的手上。

泡沫的特性

看着瓶中刚刚形成的泡沫(放大镜会有所帮助)，你会发现一群圆形气泡被肥皂水隔开，气泡间的水在重力作用下很快流失。水的流失是造成泡沫无法持久的原因之一，因为这样会削弱气泡间的薄膜，直至气泡太薄而破裂。(为了更好地了解由重力引起的泡沫破裂，研究者们计划在国际太空站失重的情况下研究泡沫。)

随着气泡膜越变越薄，这些球形气泡汇集在一起，形成一个个足球状且有着平整、光滑表面的结构。然而这些气泡表面不像足球表面大小一样，相反地，它们大小、形状各异。泡沫又会“变得粗糙不平”，这是指当气泡越变越大，气泡壁就会呈现出七彩光芒（更多的介绍见后）。几小时之后，泡沫缩小为一些薄薄的膜。最后待这些薄膜消失，瓶中又恢复为先前的半瓶肥皂水。要想再重复整个过程只需好好地摇几下瓶子。

为什么气泡是圆的?

当你再次摇动瓶子时，立刻用放大镜仔细观察新泡沫中各个独立的气泡。它们几乎都是完美的球形。这是因为气泡靠表面的能量维持形状，和其他的物理系统一

a bubble takes the spherical shape – maximum volume within minimum surface area. You can see this happen every time you blow through a plastic loop coated with a film of bubble solution to make a bubble. As you blow, the film bulges out, but it immediately starts to form the curve that will make a sphere once the bubble breaks free. And to prove that the sphere really has the least surface area, just compare the surface areas of a sphere, a cube, a pyramid, and other common shapes (all with the same volume).

In the foam bottle, the round bubbles become polyhedral (soccer-ball-shaped) because they must press together so as to fill all space in the container. That cannot be achieved with spheres. (Try stacking marbles within a box: No matter how they are arranged, there are chinks between adjoining marbles.) But more than nestling perfectly among its neighbors, each polyhedral bubble must also have minimal surface area.

Now spread a thin layer of bubbles in a shallow, clear glass container such as a petri dish. Leave just one or two layers of bubbles so that you can observe them. If you have access to an ordinary copying machine, you have a simple way to record the configuration of the bubbles as time goes on. Place the container on the glass of the copying machine and make a photocopy at 10-minute intervals. The coarsening that you will observe occurs because smaller bubbles contain air under higher pressure than that in larger bubbles. That air moves

样，气泡在能量最低的情况下最稳定，而只有球形气泡才能达到最低能量——体积最大，而表面面积最小。每次你用一个沾上一层气泡液的塑料管吹泡泡，都会看到这样的现象。你一吹，气泡胀大，一旦气泡脱离管口飞起来，很快就会弯曲变成球状。要想证明球体的表面面积最小，你可以比较球体、立方体、锥体和其他一些常见形状的表面面积（在体积相同的情况下）。

在装有泡沫的瓶中，圆形的气泡互相紧压，形成多面体（足球的形状），填满容器的空间。球体就不行了。（试着往盒中塞弹珠，无论你怎么摆放，相邻的弹珠间总有空隙。）不过除了相互完美地紧挨在一起，每个多面体的气泡都保持着最小的表面面积。

现在将一层薄薄的气泡铺在一个浅底、干净的玻璃器皿上，如皮氏培养皿。留下一两层以便观察。如果你有一台普通的投影机，你就可以按照时间的推移，简单地记录下气泡的形状变化。将容器放在投影机的玻璃面上，每隔十分钟拍摄一次。你会发现气泡变得越来越粗糙，那是因为小气泡内的空气压力大于大气泡内的空气压力。空气穿过小气泡壁进入大气泡，小气泡遂消失。同理，当空气压力大到挤压破相邻的两个气泡壁时，

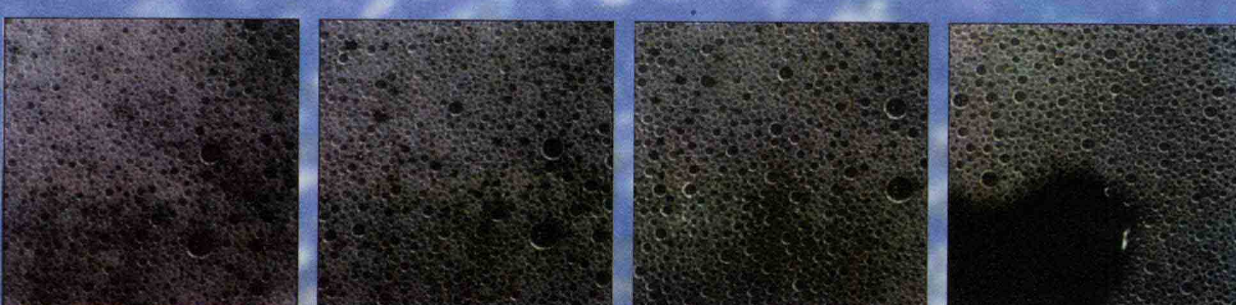


Photo by Marilyn Fletcher

A soap foam photocopied at 20-minute intervals shows dramatic coarsening after 1 hour (last box).

through the small bubbles' walls into the larger bubbles so that the smaller bubbles tend to vanish. Also, when the pressure is great enough to break a wall shared with an adjoining bubble, the result is a single bigger bubble. By analyzing the successive photocopy images, you will observe that the average bubble size increases as time passes, giving evidence of coarsening.

In addition to the coarsening property, the 19th-century Belgian physicist Joseph Antoine Ferdinand Plateau (incredibly, Plateau did much of his research while he was blind) formulated three additional properties of foam: (1) only three films – no more, no fewer – ever meet to form the edge of a bubble; (2) any two adjacent films of these three always meet at an angle of 120 degrees; and (3) only four edges – no more, no fewer – of bubbles ever come together at a point.

WHY ARE BUBBLES COLORFUL AND FOAMS JUST PLAIN WHITE?

If you look carefully at a bubble blown from bubble solution, or sitting in a foam, you see rainbows. These occur because the thin wall of the bubble breaks up ordinary white sunlight or lamplight into colors.

When a ray of white light hits a bubble wall, part is reflected from the front surface of the wall, and part continues through the wall and is reflected from its back surface. The reflected rays mingle with each other. Like all light, these rays are made of waves, and the wavelength of each wave (the distance between one peak and the next) determines the color of the light. Blue light, for instance, has a shorter wavelength than red light. As the mingled waves overlap, light at some wavelengths gets stronger and light at other wavelengths gets weaker (effects called construc-

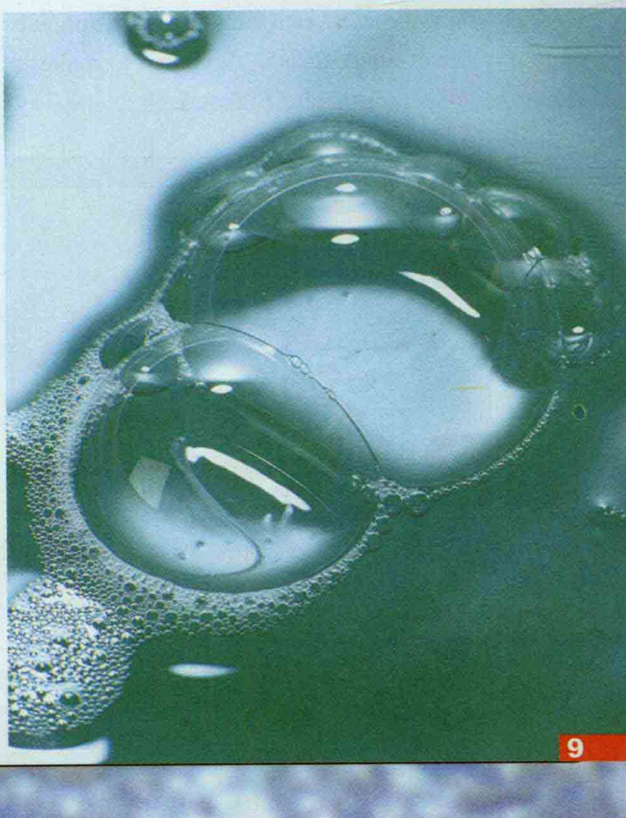
就形成一个更大的气泡。分析这些连续拍摄的图片，你会发现随着时间的推移，气泡逐渐变大，变粗糙。

除了粗糙不平的特性以外，19世纪比利时物理学家约瑟夫·安东尼·费迪南·柏拉图（难以置信的是大部分研究是在他失明时完成的）归纳出泡沫的其他三个特性：(1) 气泡面不多不少刚好三层；(2) 三层中任一相邻的两层呈120度角；(3) 不多不少刚好四个气泡面交于一点。

为什么气泡是彩色的，而泡沫却是普通的白色？

如果你仔细观察气泡液中吹出的气泡或泡沫中的气泡，你会看到七彩光芒。这是由于气泡壁将普通的白色阳光或灯光分解为各种颜色。

当一束白光射到气泡壁，一部分光线从气泡前壁反射回去，而另一部分光线则



tive or destructive interference). The curve of the bubble and the thickness of its film determine which rainbow colors you see.

But when you look at a thick foam, like dense soapsuds in a bottle or shaving cream, you don't see rainbows: You just see that the foam is white, and that you can't look through it. Both happen because a foam scatters light. A light ray that enters a foam soon encounters a bubble. That alters the direction of the ray, and another similar change in course happens every time the ray hits a bubble as it works its way into the foam. Few if any rays make it all the way through a foam.

You can show this with a low-power red pointer-type laser like those lecturers use. (By the way, this next step makes an impressive science-fair demonstration. However, any time you use even such a tiny laser, which is supposed to be too weak to hurt anyone, make sure the laser beam does not end up in someone's eye.)

First, shine the laser beam through the air. Sprinkle some powder or chalk dust in the beam to make it visible, and you'll see that the beam travels a long way

穿过气泡壁，从气泡后壁反射回去。反射的光线互相交织。和所有的光线一样，这些射线由光波组成，每条射线的波长决定了光线的颜色。譬如，蓝光比红光波长短。合成光波叠加后，有些波长的光变强，另有一些变弱（这种效果称为相长干涉或相消干涉）。你所能见到的色彩取决于气泡的曲率和薄膜的厚度。

而像瓶中高浓度的肥皂液或刮胡膏就看不到彩色，你只能看到白色、不透明的泡沫，这是因为泡沫散射了光线。射进泡沫的光线，很快就遇到气泡，气泡改变了光的方向。每当光线要进入汽泡时，就会碰到气泡而变向，这时，光线路径就会发生类似的变化。很少有光线能直接穿透泡沫。

你可以像有些演讲者那样用一台低功率红色笔式激光器试验一下。（顺便说一句，这样做好比科技博览会的展示令人印象深刻。但是，无论你什么时候使用这种理应不会造成伤害的小型激光器，都要确保激光束不会射到别人的眼睛。）

首先，将激光束射向空中。在光束中

A laser beam diffuses as it enters a foam. Few if any light rays make it all the way through.

一束激光进入泡沫时会发生散射，
几乎没有光线能穿透出去。

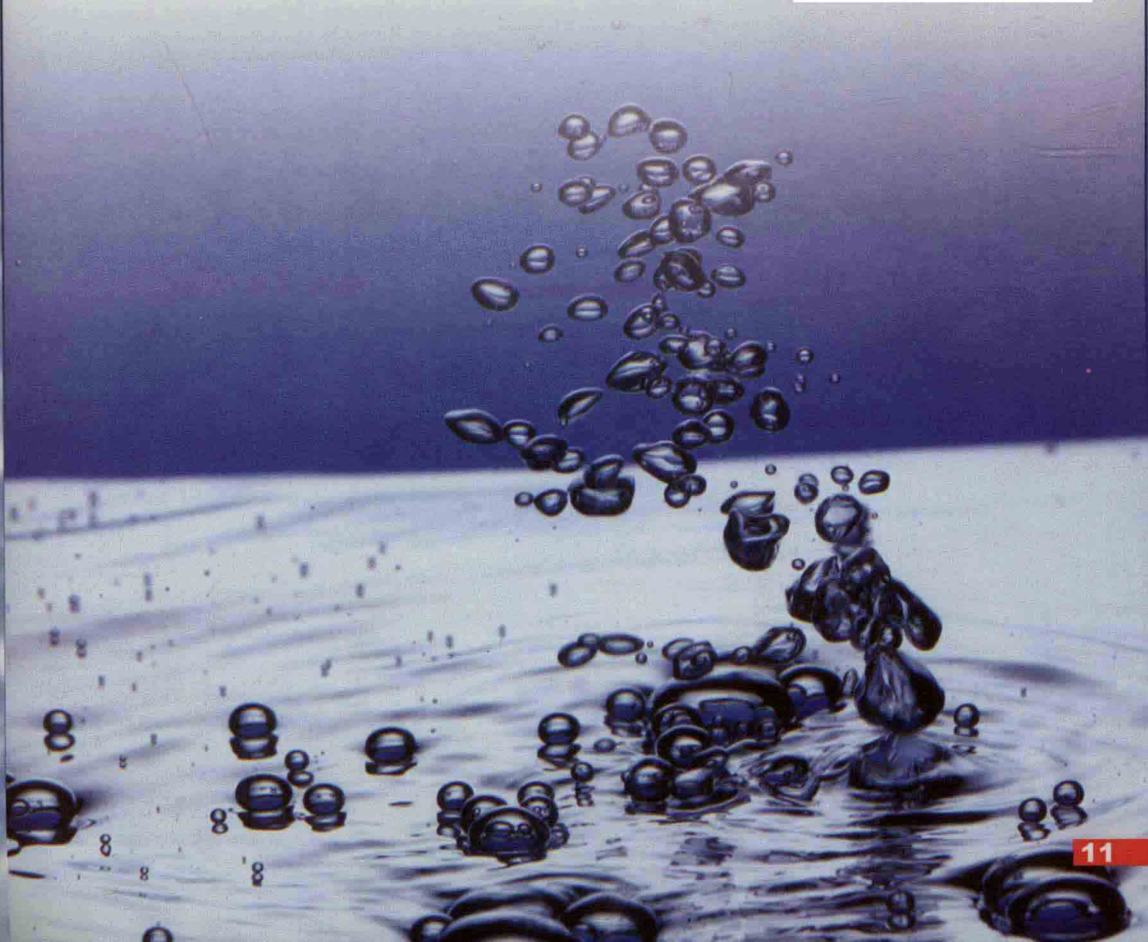
© by Photo Disc

in a straight line without losing power. Now shine the laser onto the foam in the plastic bottle. The beam spreads out or diffuses as it enters the foam, and continues to spread and weaken as it goes deeper. Probably you won't see even a trace of red light coming through the other side of the foam. In this experiment, the scattered light is the same red as the laser beam. Under ordinary lighting, however, a foam becomes filled with scattered white light, and that's why the foam looks white.

Are you bubbling with enthusiasm to try some of these experiments? Didn't I tell you that foamy "fizzicks" is lots of fun?!

撒上一些可见的粉末或粉笔灰，你会看到光束能够直射得很远而不减弱。再将激光束射向塑料瓶中的泡沫上。光束一旦进入泡沫，就会发散开去，继续深入进去后便会进一步扩散、减弱。也许你从泡沫的另一边再也看不到一丝红光了。在这个实验中，散射的光线和激光束一样是红色的。而在普通光线下，泡沫里全是散射的白色光线，这就是为什么泡沫呈现白色的原因。

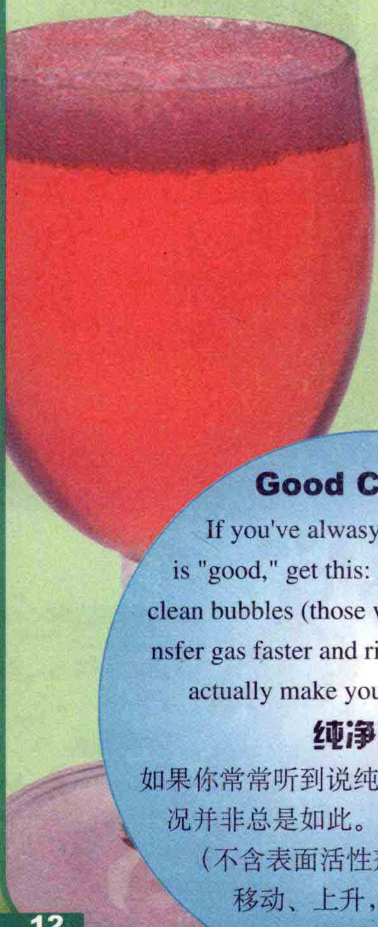
你是否已经兴奋不已，跃跃欲试了呢？我不是告诉过你关于泡沫的知识趣味无穷吗？



Bottled

***P**eople love to drink bubbles. Why else would Americans drink an average of 56 gallons of soft drinks per person each year?*

人们爱喝带气泡的饮料。为什么美国人平均每人每年要喝掉56加仑的汽水？



GETTING BUBBLES INTO THE BOTTLE

Soda is a pressurized mixture of flavored syrup and water to which carbon dioxide gas has been added. In modern bottling plants, very cold liquid and carbon dioxide (CO_2) are mixed together in big tanks called carbo-coolers, or carbonators. The colder the temperature, the more gas can dissolve in the liquid.

The bottling plant transfers the carbonated soda under pressure to bottling or canning machines. Machines fill containers and cap them immediately so that contents stay under pressure. Water sprays bring the sealed containers to room

将气泡装入瓶中

苏打水是由甜糖浆、水加上二氧化碳压缩混合而成的。在现代化的瓶装工厂里，冰冷的水与二氧化碳被放置在一个称为碳酸饱和器的大容器中混合。温度越低，液体挥发出的气体越多。

瓶装工厂把经过碳化和压缩处理的苏打水移至瓶装或罐装机器上。机器将瓶注满并迅速加盖，保证瓶内苏打水处于压缩状态不变。喷水可以使密

Good Clean Fun

If you've alwasy heard that "clean" is "good," get this: it isn't always. In fact, clean bubbles (those without a surfactant) transfer gas faster and rise faster. Clean bubbles actually make your soda go flat faster.

纯净的快乐

如果你常常听到说纯净就好，那么记住，情况并非总是如此。事实上，纯净的气泡（不含表面活性剂）会加速气体的移动、上升，使你的苏打水回落得更快。

Bubbles

by Kathiann M. Kowalski

temperature so that condensation won't form when they're packed in boxes. Then the soda goes to stores and restaurants.

封的容器达到室温，这样在装箱时就不会凝固。然后，苏打水被送往商场和饭店。

MORE BOTTLED BUBBLES

Sparkling water is generally bottled or canned like soda. Even with naturally carbonated mineral water, bottlers usually filter the water and add carbon dioxide the way soda bottlers do. That way, potential contaminants don't give the water an "off" taste.

Beer starts with a porridge of malted (soaked) barley, to which brewers add ***hops*** and special yeast. Soaking releases some of the sugar in the grain. "When the yeast gobbles up the sugar, it spits out alcohol and it spits out CO_2," explains Jonathan Satayathum at Cleveland's Great Lakes Brewing Company.

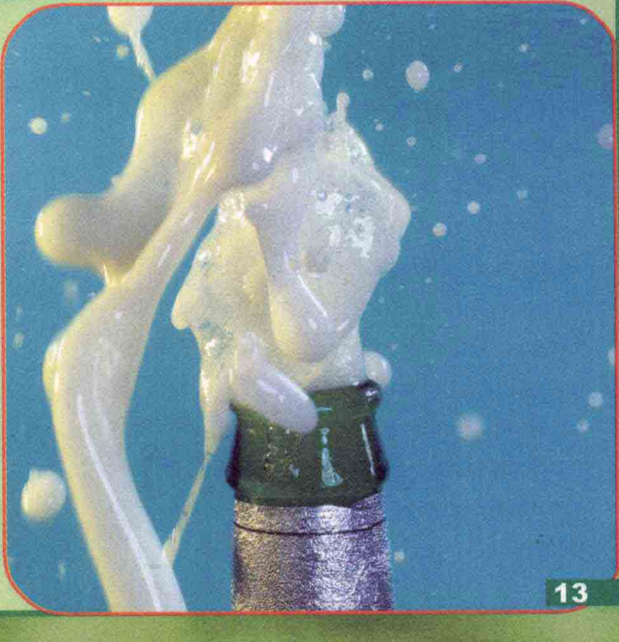
Hops
The dried, ripe flowers of a twining vine that give the characteristic bitter taste to beer

更多的瓶装气泡

和苏打水一样，汽水一般也是瓶装或罐装的。即便是经过自然碳化的矿泉水，装瓶时通常也是先将水过滤净化，再依照苏打水的制作方法加入二氧化碳。这样可以防止潜在污染物使水变味。

啤酒酿造者先浸泡大麦，再加入啤酒花和特殊的酵母制成啤酒。浸泡时谷物中的糖分被释放出来。克利夫兰大湖酿酒公司的乔纳森·萨特亚桑姆解释说："酵母吸收糖分，转化为酒精和二氧化碳。"有些酿酒厂，如同生产苏打

瓶中气泡



Some breweries release the carbon dioxide and then carbonate their product as soda companies do. Others, like Great Lakes, maintain a certain pressure in the tank. Then they transfer the naturally carbonated beer under pressure to machines that fill kegs or bottles.

Why do beer and non-alcoholic root beer form foamy "heads" when poured? As their bubbles rise, they absorb chemicals that act as surfactants. These "surface-active" chemicals like to be on the surface, says Ira Leifer at the University of California, Santa Barbara. When they are, they weaken surface tension and delay bubble bursting.

Wineries that produce champagne and fine sparkling wine use a first step of fermentation to produce a low-alcohol still wine. They bottle that, add yeast and sugar, and let it ferment again. Afterward, wineries concentrate the *lees* (dead yeast) by placing bottles at an angle on racks and rotating them periodically. The bottlenecks are frozen in a chemical solution, the bottles go on a conveyor belt, and the tops are opened. Gas pressure shoots the lees out, machines top off fluid levels, and within seconds the bottles get corked and caged. The pressure inside the corked bottle is six atmospheres, or three times the pressure in a car's tires. No wonder the bottle goes "Pop!" when it's finally uncorked!

Try This

Chill one 355-milliliter bottle of soda. Leave an identical bottle at room temperature. Fit a helium-quality balloon over each bottle cap, and attach it tightly to the neck with a rubber band. Without tearing the balloon, loosen (but don't remove) each bottle cap. Compare what happens to each balloon. Gently shake each bottle. Repeat every 10 minutes until no more bubbles form in one bottle. Which soda went flat first?

试试这个

冷却一瓶355毫升的苏打水，再留一瓶一模一样的苏打水于室温下。在两个瓶盖上分别拴一只氦气球，并用橡皮筋牢牢固定在瓶颈上。不要弄破气球，松开（不要拿走）瓶盖。比较一下两只气球各会发生什么情况。轻轻摇晃两只瓶子。每隔十分钟重复一次，直至一只瓶中不再生成泡沫。哪一瓶苏打水会先回落？

水的公司一样，在二氧化碳释放后碳化其产品。而另一些酿酒厂，如五大湖公司，则保持桶内压力，再将在压缩状态下自然碳化的啤酒装瓶封盖。

为什么在倒啤酒和不含酒精的根汁饮料时会在上面冒出一层泡沫？气泡冒出时会吸收一些类似于表面活性剂的化学物质。加利福尼亚大学圣巴巴拉分校的伊万·莱夫说，这些“激活表面”的化学物质喜欢停留在表面。它们削弱了表面张力，延缓了气泡的迸发。

生产香槟和优质发泡葡萄酒的葡萄酒厂首先通过发酵生产出低醇葡萄酒，然后装瓶，并添加酵母和糖再次发酵。之后，葡萄酒厂将一瓶瓶葡萄酒按一定的角度摆放在酒架上，定期地旋转以浓缩酒渣（已死亡的酵母）。瓶颈被冷冻在化学溶剂里，瓶子被送上传送带，瓶盖被打开。气压将酒渣排出瓶外，机器再将瓶内注满酒，几秒钟后瓶子被加塞封住。密闭的瓶内压力是六个大气压或汽车轮胎三倍的气压。难怪最后打开时，瓶子会砰的一声响。