**Speciation in Geographically Isolated Populations**

**地理隔离导致物种形成**

Evolutionary biologists believe that speciation, the formation of a new species, often begins when some kind of physical barrier arises and divides a population of a single species into separate subpopulations. Physical separation between subpopulations **promotes** the formation of new species because once the members of one subpopulation can no longer mate with members of another subpopulation, they cannot exchange variant genes that arise in one of the subpopulations. In the absence of gene flow between the subpopulations, genetic differences between the groups begin to **accumulate**. Eventually the subpopulations become so genetically distinct that they cannot interbreed even if the physical barriers between them were removed. At this point the subpopulations have evolved into distinct species. This route to speciation is known as allopatry (“allo‐” means “different”, and “patria” means “homeland”).

进化生物学家认为物种形成（也就是新物种的产生）经常是某种物理障碍（地理

隔离）的出现把一个单一物种群分为隔离的亚种群。亚种群的身体隔离促进了新

物种的产生，因为一旦亚种群中的成员无法与其他亚种群中的成员交配，那么亚

种群之间就没有变种基因的交换。缺乏了基因交流，亚种群之间的遗传差异就开

始变大。最终这些亚种群的基因差异变得十分明显，以至于它们无法进行种族内

的交配，即使它们之间的物理障碍已经消除。这时，这些亚种族就演化成了独立

的物种。这样的物种形成的方式被称作异域性。（“allo-”意思是“不同的”，

“patria”意为“故乡”）

Allopatric speciation may be the main speciation route. This should not be surprising, since allopatry is pretty common. In general, the subpopulations of most species are separated from each other by some measurable distance. So even under normal situations the gene flow among the subpopulations is more of an intermittent trickle than a steady stream. In addition, barriers can rapidly arise and shut off the trickle. For example, in the 1800s a monstrous earthquake changed the course of the Mississippi River, a large river flowing in the central part of the United States of America. The change separated populations of insects now living along opposite shore, completely cutting off gene flow between them.

异域性物种形成可能是最主要的物种形成方式。这没什么惊讶的，因为异域现象太常见了。一般而言，大多数的物种的亚种族都是被遥远距离所隔开了。所以即使在正常条件下，这些亚物种间的基因流动倒更像是一条断断续续的细流，而不是一条不停流淌的小溪。并且，障碍也会迅速出现来截断这条细流。例如，19 世纪的一次大地震改变了密西西比河（美国中部的一条大河）的流向。这个变化使得当地的昆虫分离开来，它们现在居住于河的两岸，彼此的基因流动已经完全被截断了。

Geographic isolation also can proceed slowly, over great spans of time. We find evidence of such extended events in the fossil record, which affords glimpses into the breakup of formerly continuous environments. For example, during past ice ages, glaciers advanced down through North America and Europe and gradually cut off parts of populations from one another. When the glaciers retreated, the separated populations of plants and animals came into contact again. Some groups that had descended from the same parent population were no longer reproductively compatible — they had evolved into separate species. In other groups, however, genetic divergences had not proceeded so far, and the descendants could still interbreed — for them, reproductive isolation was not completed, and so speciation had not occured.

地理隔离也能缓慢地进行，会跨越很长的时间段。我们在化石记录中找到了这种

长期证据，从中我们可以瞥见先前延续环境的破碎。比如说，在过去的冰河世纪，

经过北美和欧洲的冰川最终把种群的部分彼此切断，当冰川消退后，这些分离的

动植物种群又会连到一起。一些起源于同一母群的群体变得不再那么容易兼容—它们演化成了分开的物种。然而，在另一些群体里，遗传差异并没有那么明显，后代们还是可以种族内互相交配的——繁殖隔离并没有彻底，所以物种形成就没有发生。

Allopatric speciation can also be brought by the imperceptibly slow but **colossal** movements of the tectonic plates that make up Earth’s surface. ■About 5 million years ago such geologic movements created the land bridge between North America and South America that we call the Isthmus of Panama. ■While previously the gap between the continents had allowed a free flow of water, now the isthmus presented a barrier that divided the Atlantic Ocean from the Pacific Ocean. ■This division set the stage for allopatric speciation among populations of fishes and other marine species. ■

异域性物种的形成也可能是由构成地球表面的地壳构造板块运动所产生的，这个

运动虽略微缓慢但却异常剧烈。大约五百万年前这种地质运动形成了连接北美和

南美的大陆桥，也就是我们今天所说的巴拿马地峡。然而之前大陆间的这个缺口可以让水自由流动，而现在巴拿马地峡在大西洋和太平洋之间形成了一道障碍。这个地域分割为鱼和其他海洋物种的异域性物种形成创造了条件。

In the 1980s, John Graves studied two populations of closely related fishes, one population from the Atlantic side of isthmus, the other from the Pacific side. He compared four enzymes found in the muscles of each population. Graves found that all four Pacific enzymes function better at lower temperatures than the four Atlantic versions of the same enzymes. This is significant because Pacific seawater is typically 2 to 3 degrees cooler than seawater on the Atlantic side of isthmus. Analysis by gel electrophoresis revealed slight differences in amino acid sequence of the enzymes of two of the four pairs. This is significant because the amino acid **sequence** of an enzyme is determined by genes.

20 世纪 80 年代，约翰·格雷夫斯研究了两个紧密相关的鱼种，一种来自地峡的大西洋一侧，另一种来自太平洋那一侧。他比较了每个鱼种肌肉里的四种酶。格雷夫斯发现在低温条件下，位于太平洋一侧的鱼种里的全部四类酶比大西洋一侧的四种酶功能更好。这个发现很重要，因为太平洋的海水的水温通常要比地峡另一侧大西洋的海水低 2 到 3 度。凝胶电泳的分析显示，四对中的两对酶的氨基酸序列略有不同。这也很重要，因为酶的氨基酸序列是由基因决定的。

First, at least some of the observed differences between the enzymes of the Atlantic and Pacific fish populations were not random but were the result of evolutionary adaptation. Second, it appears that closely related populations of fishes on both sides of the isthmus are starting to genetically diverge from each other. Because Graves’s study of geographically isolated populations of isthmus fishes offers a glimpse of the beginning of a process of gradual accumulation of mutations that are neutral or adaptive, divergences here might be evidence of allopatric speciation in process.

根据这些观测，格雷夫斯得出了两个结论。第一，在这些观测到的大西洋和太平

洋鱼种体内酶的差异中，至少有一些不是偶然的，它们是适应进化的结果。第二，似乎地峡两侧原本密切相关的鱼种开始有了基因分化。因为格雷夫斯关于地峡鱼

类地域隔离的种群研究为中性或适应性突变的逐渐累积过程的开始提供了一些线索。这里的差异可能会给正在进行的异域性物种的形成提供证据。