**Biological Clocks**

**生物钟**

Survival and successful reproduction usually require the activities of animals to be coordinated with predictable events around them. Consequently, the timing and rhythms of biological functions must closely match periodic events like the solar day, the tides, the lunar cycle, and the seasons. The relations between animal activity and these periods, particularly for the daily rhythms, have been of such interest and importance that a huge amount of work has been done on them and the special research field of chronobiology has emerged. Normally, the constantly changing levels of an animal's activity—sleeping, feeding, moving, reproducing, metabolizing, and producing enzymes and hormones, for example—are well coordinated with environmental rhythms, but the key question is whether the animal's schedule is driven by external cues, such as sunrise or sunset, or is instead dependent somehow on internal timers that themselves generate the observed biological rhythms. Almost universally, biologists accept the idea that all eukaryotes (a category that includes most organisms except bacteria and certain algae) have internal clocks. By isolating organisms completely from external periodic cues, biologists learned that organisms have internal clocks. For instance, apparently normal daily periods of biological activity were maintained for about a week by the fungus Neurospora when it was intentionally isolated from all geophysical timing cues while orbiting in a space shuttle. The continuation of biological rhythms in an organism without external cues attests to its having an internal clock.

生存与繁衍通常需要动物的活动与他们所能预料到的事件同步。生物的计时与交替循环的机能也就理所应当的必须与像昼夜交替，潮涨潮落，月圆月缺和四季更迭这样的周期性事件保持大体的一致。动物的活动与这些周期之间的关系，特别是与昼夜交替之间的关系，因为大量的工作都是在其基础之上完成的而拥有巨大的吸引力和重要性，从而也延伸出了一个新的研究领域：生物钟学科。通常意义上讲，动物活动的经常性转变——例如，睡觉，喂食，活动，繁殖和产生酶与荷尔蒙，都是与环境的循环同步的，但是关键问题在于，动物的作息是否是由外界条件驱使，比如日出日落，又或者是受他们自身产生并遵循的内在生物循环，生物学家普遍接受的观点是所有的多细胞生物（除了细菌与一些海藻以外的绝大多数物种）都有内在钟。通过将生物与外界的周期性暗示完全隔离，生物学家们发现生物确实有内在钟。举个例子，通过一种叫脉孢菌的细菌清晰的证明了在绕地球公转的太空飞船中完全与所有地理事件信号隔离的情况下，所有的生物日常活动周期可以持续大概一个礼拜左右。这种在没有外界信号的时候生物循环的延续性证明生物是具有内在钟的。

When crayfish are kept continuously in the dark, even for four to five months, their compound eyes continue to adjust on a daily schedule for daytime and nighttime vision. Horseshoe crabs kept in the dark continuously for a year were found to maintain a persistent rhythm of brain activity that similarly adapts their eyes on a daily schedule for bright or for weak light. Like almost all daily cycles of animals deprived of environmental cues, those measured for the horseshoe crabs in these conditions were not exactly 24 hours. Such a rhythm whose period is approximately—but not exactly—a day is called circadian. For different individual horseshoe crabs, the circadian period ranged from 22.2 to 25.5 hours. A particular animal typically maintains its own characteristic cycle duration with great precision for many days. Indeed, stability of the biological clock's period is one of its major features, even when the organism's environment is subjected to considerable changes in factors, such as temperature, that would be expected to affect biological activity strongly. Further evidence for persistent internal rhythms appears when the usual external cycles are shifted—either experimentally or by rapid east-west travel over great distances. Typically, the animal's daily internally generated cycle of activity continues without change. As a result, its activities are shifted relative to the external cycle of the new environment. The disorienting effects of this mismatch between external time cues and internal schedules may persist, like our jet lag, for several days or weeks until certain cues such as the daylight/darkness cycle reset the organism's clock to synchronize with the daily rhythm of the new environment.

小龙虾在黑暗中持续的活动哪怕是四五个月，他们的复眼也仍然继续按日常循环的昼与夜来调节视野。马蹄蟹可以在黑暗中保持一年的连续性大脑周期活动来使他们的眼睛适应日常交替的高光与弱光的周期一致。如同大多数的日循环动物被剥夺了外界暗示一样，对于马蹄蟹来说在这种无光的情况下他们的时长也不一定是准时的 24 小时。这种和一天的循环周期很接近但不精确同步的循环叫做生理节奏。不同的马蹄蟹个体，生理节奏在也 22.2 小时到 25.5 小时之间。一种特定的动物会将其特有的精密循环长度保持很多天。确实，稳定性是生物钟最重要的特性之一，即使是在生物所处的环境的诸多要素中发生了相当大的改变，例如温度，不能对生物钟产生很大影响。关于生物钟持续性更进一步的证据出现在当正常的外部循环发生突变，如科研或者从东到西急速的长途旅行。动物的内在以天为单位的典型周期循环活动仍然会继续而不会有什么改变。但与此同时，生物的活动与却因为与新环境中的外部循环相关联而改变。外部时间与内在循环的持续性不同步而产生的错乱反应，比如我们的时差综合症，要耗费几天或者几个星期直到不变信号比如白天黑夜循环重新设定生物钟并将其同步到新环境的日常循环中。

Animals need natural periodic signals like sunrise to maintain a cycle whose period is precisely 24 hours. ■Such an external cue not only coordinates an animal's daily rhythms with particular features of the local solar day but also—because it normally does so day after day-seems to keep the internal clock's period close to that of Earth's rotation. ■Yet despite this synchronization of the period of the internal cycle, the animal's timer itself continues to have its own genetically built-in period close to, but different from, 24 hours. ■Without the external cue, the difference accumulates and so the internally regulated activities of the biological day drift continuously, like the tides, in relation to the solar day. ■This drift has been studied extensively in many animals and in biological activities ranging from the hatching of fruit fly eggs to wheel running by squirrels. Light has a predominating influence in setting the clock. Even a fifteen-minute burst of light in otherwise sustained darkness can reset an animal's circadian rhythm. Normally, internal rhythms are kept in step by regular environmental cycles. For instance, if a homing pigeon is to navigate with its Sun compass, its clock must be properly set by cues provided by the daylight/darkness cycle.

动物需要例如日出这样的自然界的周期信号来保持他们的循环周期为精准的 24小时。这类的外部信号不仅可以通过特定的标志——当地的白昼同步动物的每日循环，而且也正是因为这些活动日复一日的保持着内在钟的周期接近地球自转。但是尽管有这些内在钟的同步，动物的计时器仍然继续靠着它构筑在遗传上的区别于外部的周期，近似 24 小时。在没有外部信号时，不同的收集方式和这种内在的调节机制作用下的生物活动保持这继续，比如潮汐，就与太阳有关系。这种调节被广泛的研究在许多动物和生物活动调节从孵化的果蝇卵到松树的滚轮跑。光在调节生物钟里占主导位置。即使是 15 分钟的强光在黑暗中发生也可以改变动物的生理节奏。通常来讲，内在循环会紧随环境循环的步伐。举个例子，如果一个家鸽在太阳的指引下飞行，那么它的生物钟就必须严格遵守日出日落的循环。