GRAVITATIONAL BIOLOGY AND FUTURE PROSPECTS - PART I

HOW GRAVITY CAN BE ALTERED?

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What is gravity?

The four basic fundamental physical forces that exist in nature are: weak nuclear force, strong nuclear force, electromagnetic force, and gravity. Out of all these forces, gravity is the weakest. Gravity, as we all know, is the constant physical force that has been known to have shaped the universe and life on Earth. Newton's law of gravitation states that "every particle in the universe attracts every other particle in the universe with a force that is proportional to the product of the masses and inversely proportional to the square of the distance between the particles". The law is expressed in mathematical form as follows:

$$F = G\frac{m_1 m_2}{r^2}$$

where, m_1 and m_2 are point masses

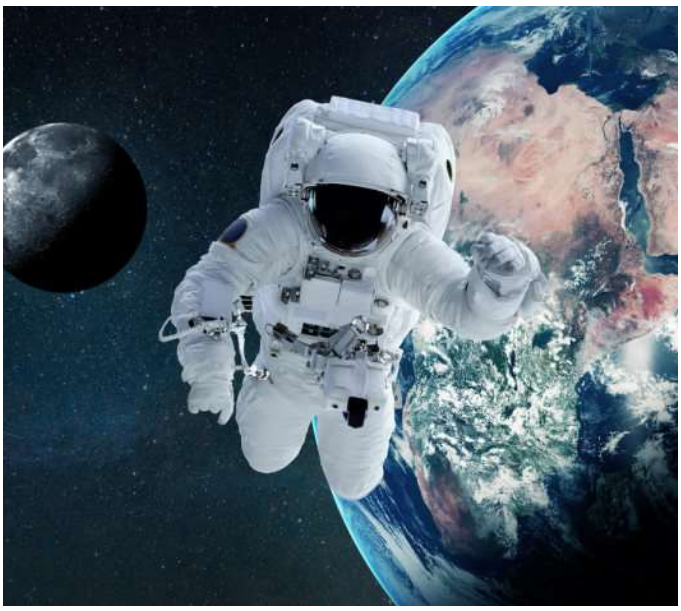
r, is the distance between these point masses

G, is universal gravitational constant

$$G = 6.67 \text{ X } 10^{-11} \text{ N.m}^2\text{.kg}^{-2}$$

From the above equation, it turns out that the acceleration effect of the small mass body m_1 (for example, living beings such as humans, plants, and animals) on a large mass body m_2 (for example, Earth) will be so negligible that the large mass body will always attract the small body. This is the reason everything that is resident on the surface of Earth is greatly affected by the Earth's 1g environment. It includes an apple that fell on Newton's head, a burning candle or a falling water droplet, humans anchored to the Earth's surface, and many other phenomena. The question is: how do we study these effects?

To embark on a journey of unraveling the mysteries of gravity and the role it plays in shaping life forms, it is important to change its magnitude while keeping other physical parameters constant and understand its effect. The removal of gravity is a desirable, even necessary, step toward understanding its role in living organisms. In a sense, the removal of gravity for studying the gravity-sensing mechanisms is like switching the light for studying the role of vision. Before we understand its effect, let's try to see how gravity can be changed.

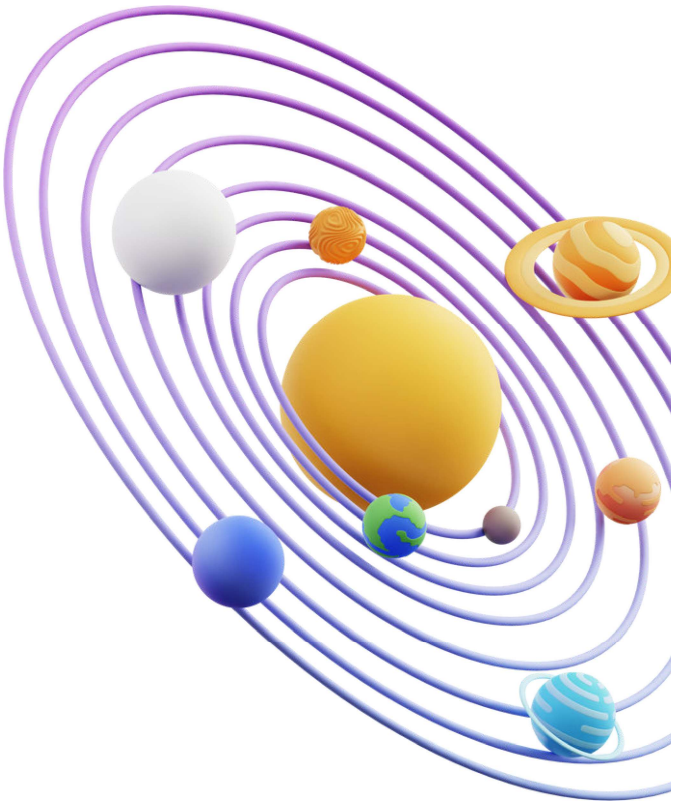


How can gravitation be altered?

Different planets exhibit different gravity based on their mass and radius. Understanding how gravity changes is fundamental to many fields of science and engineering, from astronomy to space biology and space exploration. Different astronomical bodies have different magnitudes of gravity due to their mass, size, and density, as shown below in Table 1.

Table 1: g values on the surface of various astronomical bodies in the solar system

Astronomical Body	Mass m 10^{23} kg	Radius R 10^{6} m	g, m/s^2	g, units
Sun	19890000	695	275	27.99
Mercury	3.3	2.44	3.7	0.38
Venus	48.69	6.0518	8.87	0.91
Earth	59.72	6.37815	9.81	1
Moon	0.735	1.738	1.62	0.17
Mars	6.4219	3.397	3.71	0.38
Jupiter	19000	71.492	24.8	2.52
Saturn	5680	60.268	10.4	1.07
Uranus	868.3	25.559	8.87	0.91
Neptune	1024.7	24.766	11.1	1.14



Depending upon the magnitude of acceleration 'g', gravity can be broadly classified as microgravity (μg) or low gravity, whose g value nearly lies between 10^{-3}g and 10^{-6}g; hypogravity, whose g value is greater than 10^{-3}g to 1g; and hypergravity, whose g value is more than 1g. Here, 1g is considered the Earth's acceleration due to gravity, i.e., 9.8 m/s^2 in SI units. These different gravity conditions can be achieved in various ways. The success of modern space technology has made possible experiments on living systems in a true microgravity or weightlessness environment, such as parabolic spaceflights, drop towers, sounding rockets, etc. Parabolic flight provides a real microgravity environment, but it is limited in duration. The parabolic flight starts with an initial climb and reaches a plateau by reducing lift and thrust, which produce approximately 25 seconds of 0g and begin to fall down (Figure 1). Drop towers are maintained under vacuum and consist of a scientific experiment platform. An object can be dropped from a certain height to achieve microgravity for several seconds during a free fall.

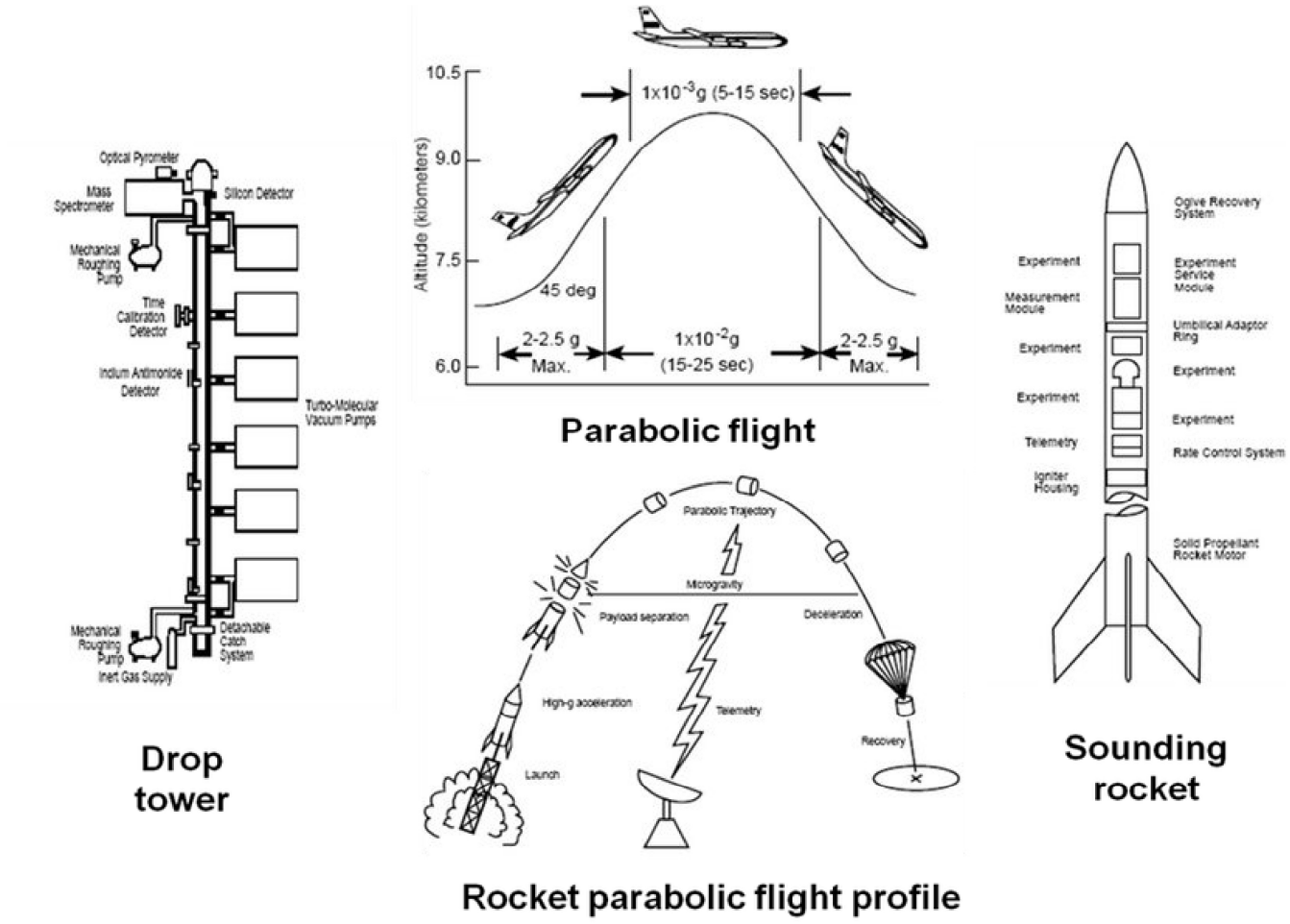


Figure 1: Altered gravity platforms

Although facilities like parabolic flights, drop towers, and sounding rockets have the advantage of producing a microgravity environment, they pose the common problem of limited exposure duration. Since the opportunity for experiments in space is limited, ground-based experiments are still mainstream in the study of gravity responses in living systems. On Earth, clinostats, random positioning machines, rotating wall vessels, and magnetic levitation are some of the other useful experimental platforms for simulated microgravity. Acceleration due to centrifugation is used to obtain the hypergravity condition and to analyze the mechanisms of gravity perception and response in living organisms.

In next issue let's understand how altered gravity affects biological systems.

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