Anesthetics, Anesthesia and Plants

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Abstract

General anesthesia, its nature and how it exactly works, are still poorly understood. Plants can also be anesthetized and lose their responses to external stimuli. Interestingly, plants are known to produce endogenous anesthetic compounds to deal with stress. Plants offer an excellent model object for studies on anesthetics and anesthesia.

Anesthetized plants

General anesthesia has been used for the purpose of medical treatments since their effects were coincidently discovered about 200 years ago. Many attempts to give a scientific explanation how these compounds function on nervous system have been made. However, it is still a big mystery why so many different types of chemical compounds show the same effect in humans and animals, loss of consciousness [1]. We recently reported that general anesthesia does immobilize leaf-moving plants, such as *Mimosa pudica* or Venus flytraps due to loss of action potentials [2]. Venus flytraps no longer generate electrical signals and their leaf traps remained open when the trigger hairs were touched [2]. Moreover, pea tendrils stopped their circumnutation movements and were immobilized in a curled shape [2]. The results of this study suggest that the lack of plant organ movements is due to the inhibition of plant-specific action potentials. In addition, the generation of reactive oxygen species and the disturbance of endocytic vesicle recycling were also observed using Arabidopsis cells (Figure 1) [2]. We also found an impact of general anesthesia on plant-specific events of development. Termination of seed dormancy and biosynthesis of chlorophyll were strongly inhibited under anesthesia.

Importantly, the effects of anesthesia were reversible, as all these processes quickly resumed immediately after anesthetic drugs were removed. Action potentials, reactive oxygen species and endocytic vesicle recycling are common important cellular events both in plants and animals and these were susceptible to anesthesia. The results suggest that anesthetics could target similar cellular components shared by many living organisms (figure 1 and see TEXT BOX). Therefore, we propose that plants can serve as model organisms to study the underlying mechanisms to how anesthesia works, and may be useful in unlocking the process in humans well after its first use almost 200 years ago.

Anesthetic actions in animals and plants

Although the mechanism of anesthetics in living cells have been unclear, there were two possible targets have been proposed in the research history, lipid membrane vs. specific membrane protein. The former is well-known as the “Meyer-Overton theory of anesthesia” that explains the correlation between the solubility of anesthetic molecules within lipid membranes and their anesthetic properties [1]. The theory postulated that lipid-soluble compounds could act as the anesthetics when these reach certain critical concentrations in the membrane. After genetics emerged, many anesthesia studies have shifted their focus to identify the specific protein targets of anesthetics. The favored model of anesthetics actions is that they bind to neurotransmitter receptors, especially to glutamate and GABA receptors. Intriguingly, the existence of plant-specific glutamate and GABA receptors has emerged for signaling in control of growth, stress responses, and development [7-10]. Similar to processes found in animals and humans, GABA lowers and glutamate increases membrane excitability, but there is also a model in plants of physical actions of anesthetics targeting membranes and electrons [1,11]. In addition, voltage-gated ion channels are also proposed to act as the targets of anesthesia in animal and human neurons [1]. Importantly, plants also express very similar channels. This implicates that anesthetics could have the same targets in living cells.

Application of anesthesia for plant and general sciences

In the early 1900s, anesthetic chloroform was once used by gardeners to force early blooming of lilac flowers, to ensure that flowers were ready to be sold at Christmas. Normally lilac flowers need a long winter phase to prepare for bloom and would only flower in spring time. It appears that gardeners empirically knew that the treatment of anesthesia shortens the period of “winter rest” and took advantage of it. In 1920, Indian Sir J. C. Bose performed anesthesia on large trees with chloroform, allowing their transplantation without serious damages to such trees. He used a huge tent to cover a whole tree and filled the inside with chloroform. According to our recent report [2], general anesthetics inhibit chlorophyll biosynthesis and the termination of seed dormancy. Although the underlying mechanisms of these actions of anesthetic compounds are still unclear, the sensitivity of plants to anesthetics could be useful in terms of the application of drugs for research of plant sciences, or in the field of agriculture and horticulture. Intriguingly, plants produce numerous endogenous anesthetics [3], especially when they are stressed or wounded [3,6]. Of these anesthetics, ethylene and divinyl-ether are mainly characterized as stress and dormancy hormones [4-6], but are rarely discussed from the anesthetics point of view. It might be that signaling pathways connected to stress responses, including pathogen attacks, will be sensitive to anesthetics. These are urgent questions for further studies. Finally, plants can serve as model objects to unravel mysteries of anesthesia in general and to advance the discovery and applications of anesthetics in medicine.

TEXT BOX

French physiologist Claude Bernard performed many anesthetic experiments in the last 10 years of his life before his death in 1878 in Paris. He convincingly demonstrated that leafs of *Mimosa pudica* were unresponsive upon touch stimuli under diethyl ether atmosphere (Figure I from p. 259 in [12]). He performed many experiments in animals and plants and arrived at the conclusion that ‘…plants and animals must share common biological essence that must be disrupted by anesthetics.’ [12]. Our recent report on anesthesia and plants was conducted based on Bernard’s work [2].

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Figure legends

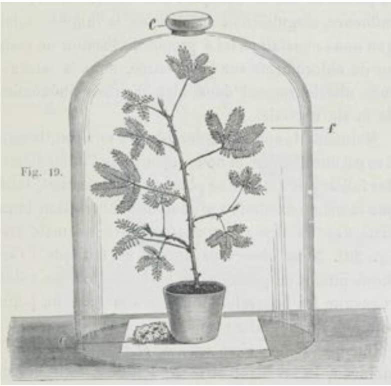

Figure I. Bernard’s ether experiment. Anesthetized mimosa plant with ether-containing sponge.

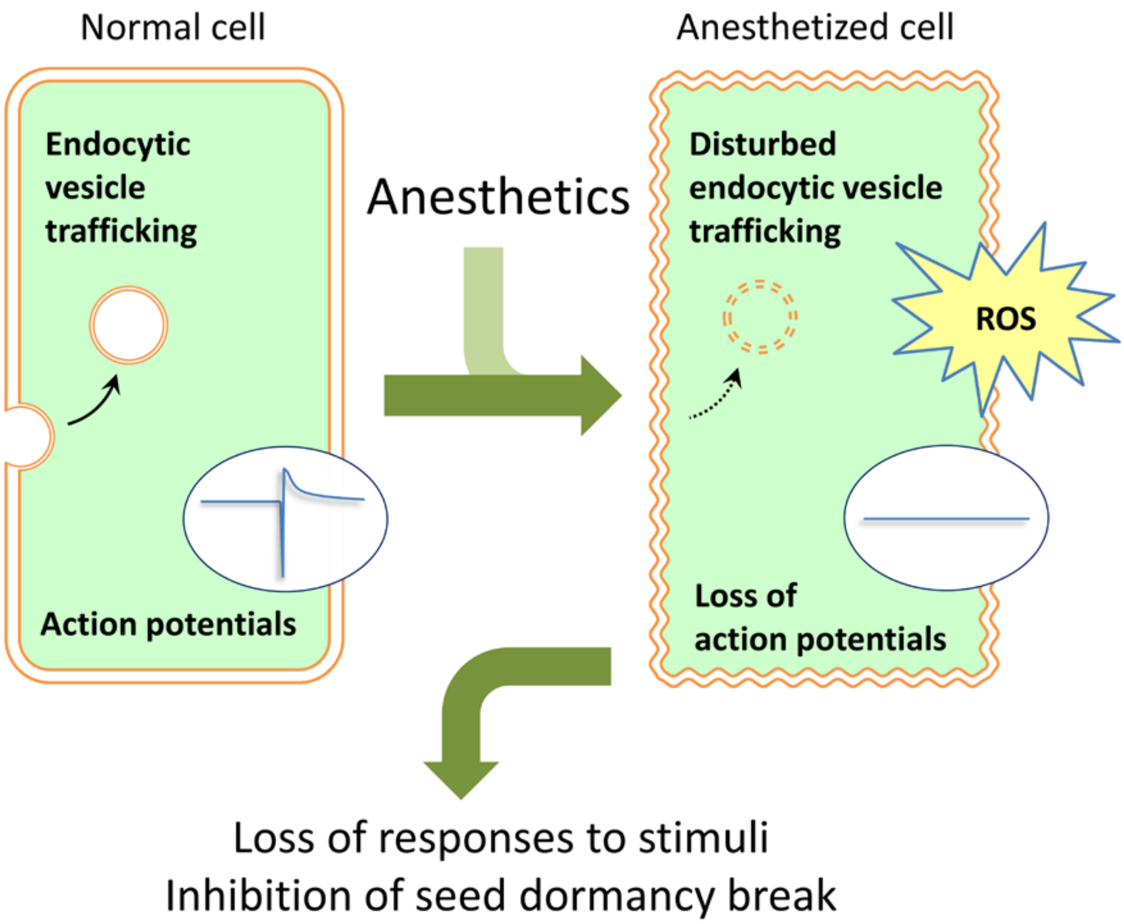

Figure 1. A proposed model of a plant cell under anesthesia. Anesthetics block plant action potentials. Membrane trafficking is disturbed and excessive reactive oxygen species (ROS) are generated rapidly [2]. These quick cellular responses lead to the loss of response to external stimuli and inhibition of break of seed dormancy. Double-line depicts plasma membrane of cell, compromised in cells under anesthesia.