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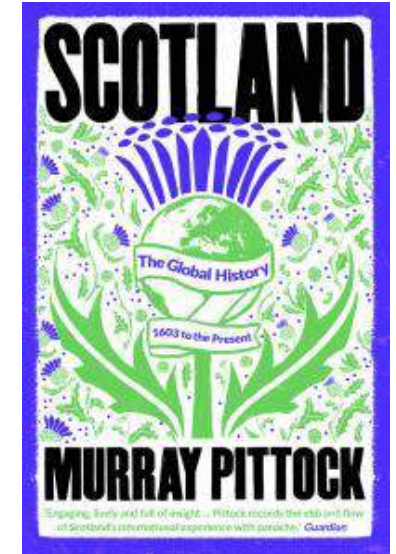
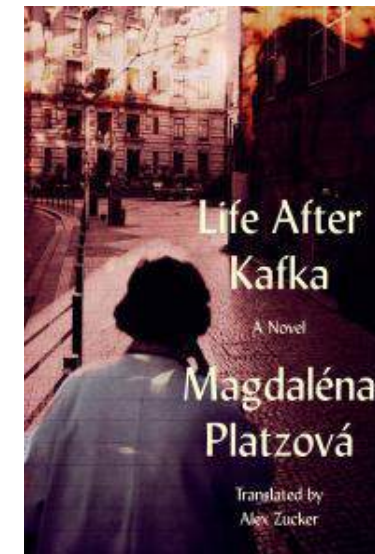
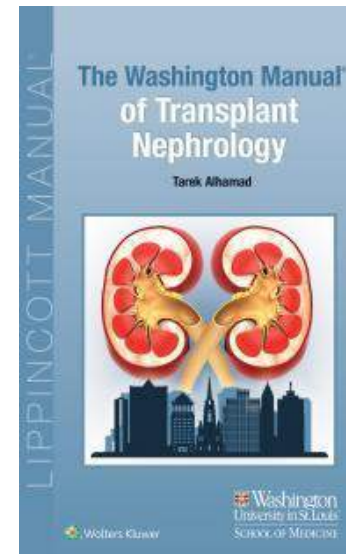
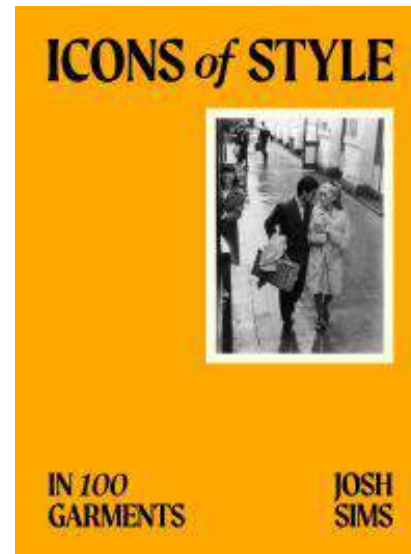
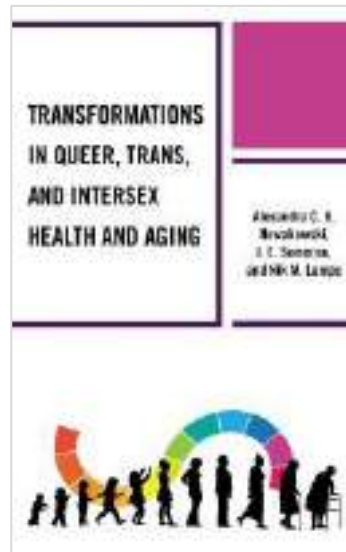
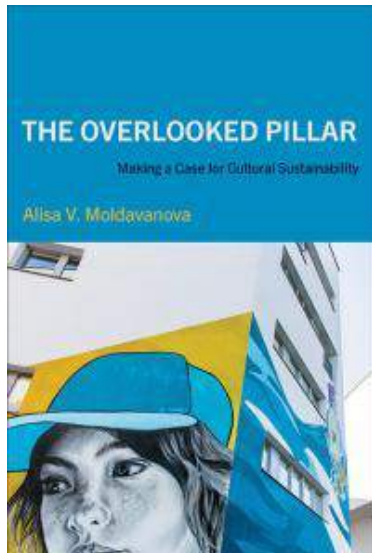
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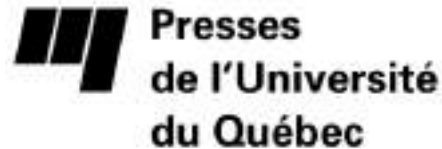
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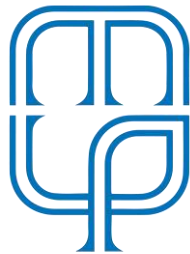
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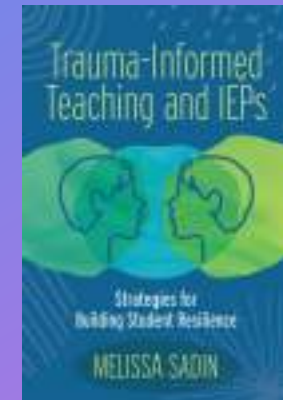
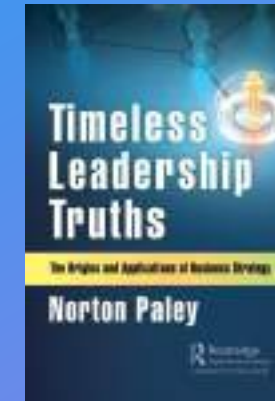
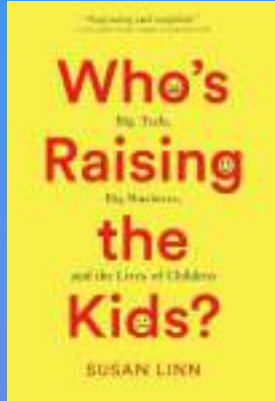
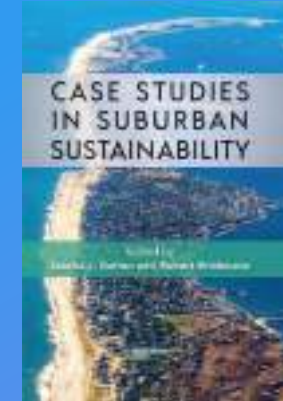
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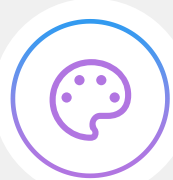
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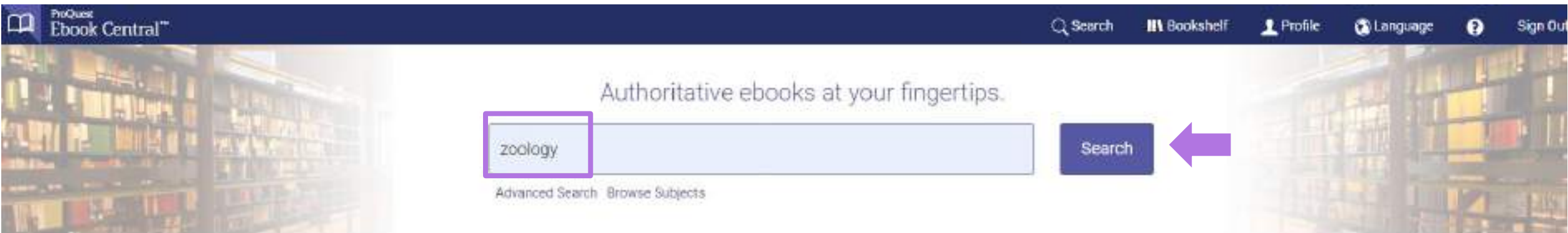
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University of California Press 2003  
ISBN: 0780320238113, 9780520930301  
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pg. 1-1; 1 page

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Charitable Organizations

- Preserve and protect the environment,<sup>42</sup> including instituting litigation as a party plaintiff to enforce environmental protection laws<sup>43</sup> and conducting legal research to settle international environmental disputes through mediation.<sup>44</sup>
- Promote world peace, except through illegal protests.<sup>45</sup>
- Maintain and set aside public parks and wildlife areas.<sup>46</sup>

Organizations qualifying in this category operate to benefit the community, which may be a town, the state, or the world. Under the social welfare umbrella, a legislative initiative to adopt laws to achieve the change can be used to accomplish the organization's goals. If the social welfare can be promoted only through passage of legislation, however, the action organization rules may prevent charitable status.<sup>47</sup>

**(a) Low-Income Housing**

Low-income housing and economic development projects receive significant government funding. As a result, the policies affecting them are subject to change as the persons in charge of their local, state, and federal funding sources change and, correspondingly, the standards for tax exemption change. Some low-income hous-

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## Cuchulainn the Hound of Culann

Cuchulainn's mother was the daughter of a king. He was the son of the king's daughter. Deichtine, sister of the king, was born at the same moment as the Black of Seingliu.

Like many other mythic heroes, Cuchulainn's deeds began when he was a boy. When he arrived late at a banquet given in the house of Culann, a great craftsman and smith, he was confronted by the smith's hound, which growled and snarled at him. Threatened by the ferocious dog, the boy stuffed a ball down the beast's throat, and as it choked, he smashed it against a wall, killing it. Culann mourned his loyal animal, and the boy, regretting his deed, said that he himself would perform the duties of the hound. Thus he gained his name, the Hound of Culann.

Like most great heroes, Cuchulainn is armed with magical weapons; these include his spear, which inflicts only fatal wounds, and a visor given him by the sea god, Manannan mac Lir. In battle a fury comes over him so that he seems transformed into a monster, filled with rage and bent on destroying his foes.

## The Cattle Raid of Cooley

The central tale of the Ulster Cycle is known as the Cattle Raid of Cooley (the Tain bó Cuailnge), which tells the tales of two magical bulls. These are Donn Cuailnge, the brown bull of Cooley, and Finnbennach, the white-horned bull of Ulster. The white-horned bull belongs to the wealthy, powerful, and exceedingly avaricious Queen Medb (Maev), whose enormous greed cannot be satisfied. Medb wishes to humiliate her ineffectual husband, Ailill, and desires to add the brown bull to her already prodigious wealth. Upon hearing of the mysterious affliction of the Ulster men, she set off with her armies to seize the great bull.

Medb's armies are not aware of the existence of Cuchulainn, however, and soon meet with furious resistance. Clever Cuchulainn invokes the ancient right of single

combat and staves off Medb's army for months, slaying every champion the queen sends to meet him.

## The Bulls of Cooley

The brown and white bulls of the Cooley saga are no ordinary bulls, of course, but the result of a magical battle between two enchanted shape-changers, a pair of foolish magicians whose end came in a most fitting way.

Cuchulainn's distractions are successful, and the men of Ulster, recovered from their labor pains, are able to easily defeat Medb's depleted forces.

But Queen Medb is clever. She succeeds in stealing the bull anyway, while the men are distracted by the battles. In the end, all the fighting is to no avail. The two bulls, having picked up an old disagreement, soon commence battling between themselves over which is superior. The battle between the bulls rages all night and ranges the breadth of Ireland, until at last the white-horned bull Finnbennach lies dead. The brown bull, now bored, breaks free and returns to his home in Ulster, where he too expires from his exertions.

Medb, of course, is not finished with Cuchulainn, and seeks her revenge on him through more trickery. Cuchulainn, like most Celtic heroes, is under a geas, a magical proscription which becomes a curse if broken. Cuchulainn's geas is that he must accept any meal offered him but he must never eat dog's meat. When the geas is discovered, Medb's simple solution is to offer the hero a meal of dog's meat. Spiritually broken, Cuchulainn is easily defeated, felled by the spear of Lugaid, said to have been forged by Vulcan.

## The Book of Celtic Myths : From the Mystic Might of the Celtic Warriors to the Magic of the Fey Folk, the Storied History and Folklore of Ireland, Scotland, Brittany, and Wales

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### 8 Insects That Use Plant Defenses for Their Own Protection

#### 8.1 Introduction

Diverse chemical defenses in plants, with strong odors, bitter tastes, or toxic properties, deter many insects from eating the plants (see Chapter 4). Yet, there are numerous examples where insects have not only adapted to feed on such plants, in spite of the defensive compounds, but they have also developed mechanisms to store the targeted plant defenses in their bodies and use them for their own protection. Predators like birds that eat the insects become sick and learn to avoid them. Bright warning colors (i.e. the aposematic colors) frequently alert potential predators about the toxicity or poor taste of these insects. Examples of insects that store toxins and exhibit warning colors have appeared earlier in this book in various contexts, e.g. in Figure 1.1 in Chapter 1 and Figure 5.10 in Chapter 5. You will find more examples in this chapter.

A variety of mechanisms enable certain insects to store plant toxins. Some insects sequester the plant defenses in select, well-separated parts of their bodies. Other insects can utilize or eliminate the toxic properties of the compounds by modifying them to related, non-poisonous compounds. The defensive compounds may be converted back to the toxins in animals preying on the insects. Many mesophagous and oligophagous insects, i.e. insects that specifically feed on one type of plant or a few related plants, are connected with host plants that feature distinct chemical defenses. The numerous sequences of short life cycles strongly support natural selection of those insects that can adapt to otherwise deterring plant compounds and that can even use them in their own defense.

Many types of butterflies and moths are known to acquire toxicity from plants because their larvae, the caterpillars, feed on poisonous plants. The emerging adults mostly sip flower nectars, but they still contain enough of the chemical defenses in their bodies to make predators that eat them ill. Aphids, members of the superfamily Aphidoidea, are widespread sap-sucking insects, and many of them are plant pests in agriculture. Their numerous life cycles per year, especially in mild climates, allow them to quickly adjust not only to environmental conditions, but also to host plants and their chemistry. Many plants that contain toxins have specialized aphids that feed on them in spite of the defensive compounds. In the process these aphids ingest chemical protection for themselves.

This chapter presents classic examples of coevolution between insects and plants. Through evolution many plants developed chemical defenses as a protection against herbivorous insects. In response, many phytophagous insects have counteradapted to the plant defenses and sometimes even use them for their own defense. Compare these mutual adaptations with those that evolved – and that keep evolving – between plants and their insect pollinators (Chapter 2).

The following chapter sections describe specific examples of insects that obtain chemical protection from plants. The descriptions also point out the chemical characteristics of the defensive compounds involved.

#### 8.2 Monarchs, Milkweeds, and Cardiac Glycosides

Monarch butterflies (*Danaus plexippus*) have long fascinated people because of their far-reaching seasonal migrations, but also because of their toxicity to birds that try to eat them. The connection between milkweeds (*Asclepias* sp.) serving as food plants for the monarch caterpillars and the toxicity of the adult butterflies was suggested by E. B. Poulton as early as 1914.<sup>1</sup> This work presents a famous case of the intersection of biology and chemistry and illustrates a classic example of insects specializing on toxic host plants and using the poisons for their own protection. Milkweed plants (*Asclepias* sp., Family Apocynaceae) are native to North and Central America. Their common name alludes to the white latex in all parts of the plants (compare Chapter 4.8). Their systematic name, *davylepis*, was suggested by the botanist Carl Linnaeus. It is related to *Asclepius*, the Greek god of healing, because of the heat-active properties of milkweed plants. Dapning studies on how insects are able to detoxify and thus tolerate the chemical defenses demonstrate continued interest in these insect-plant interactions.<sup>2</sup>

Figure 8.1 shows various stages of the monarch's life cycle: a caterpillar eating milkweed leaves (Figure 8.1(a)), the fully developed butterfly feeding on flower nectar (Figure 8.1(b)), and a cluster of overwintering monarch butterflies (Figure 8.1(c)), a phenomenon that is part of the annual migration of the hibernates. Note the warning colors of the insects. The mechanisms that enable monarch butterflies and their caterpillars to store the toxic defenses are still under investigation.



Figure 8.1 Life stages of the monarch butterfly (*Danaus plexippus*). (a) Monarch caterpillar feeding on milkweed (*Asclepias* sp.). (b) Adult monarch butterfly feeding on nectar of *Zinnia* flowers. (c) Cluster of overwintering monarch butterflies.

Aside from the monarch butterfly there is a suite of other insects that also feed on *Asclepias* species. Milkweed beetles (*Meligethes lateralis*/var., Figure 1.3(b)), milkweed bugs (*Oncopeltus fasciatus*, Figure 1.6(c)), and milkweed (or cluster) aphids (*Aphis* spp., Figure 4.17(b)) all ingest the plants' toxic latex without harm and use them for their own defense. Note that all these insects display bright warning colors. Leaves and stems of milkweeds contain a particularly high concentration of the toxins in their "milk" or latex, with the highest pressure of the latex in the veins of the leaves (compare Chapter 4.8). These insects have adapted to ingest small portions of the leaves, often eating plant veins first to release the poisons. Thus the dose of the ingested toxins is low and tolerable for the insects. As a further benefit, the food plants survive.

The toxicity of the plants' latex is mainly due to cardiot glycosides. As the insect "cardiac" implies, these compounds affect (and inhibit) the proper functioning of the heart muscle. The determination of the structures of these compounds – with thoughts of potential medicinal applications – was the topic of intense research in the 1950 s.<sup>3</sup> The chemical structures of cardiac glycosides consist of three general components: a steroid backbone structure (shown with conventional numbering and labeling in 8.1 in Figure 8.2), a sugar moiety attached to C3 of the steroid ring system, and a characteristic ring attached to C17. Check each of the structures shown in Figure 8.1 for these three components.

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Chemistry of Plants and Insects : PL...

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Have you ever wondered how plants attract certain insects, or how insects communicate with each other? This book explains the natural chemical compounds that determine the fascinating interactions between plants and insects providing a gentle and absorbing introduction to organic chemistry that is highly relevant to everyday life and to the natural world. Specific organic compounds and intriguing chemistry determine whether insects are keen on feeding on plants or avoid certain plants altogether. Some insects have learned to use plant compounds as their own defences, and some plants use digestive processes to use insects as nutritional supplements. Plant-insect interactions are vital for our food supply, for pollination of orchards or detrimentally in insect infestations of crops, as well as in applications like silk production. By the author of the popular book, The Chemistry of Plants: Perfumes, Pigments, and Poisons, this book benefits from Margareta Séguin's vast experience leading field trips over continents on botanical expeditions.

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## 8 Insects That Use Plant Defenses for Their Own Protection

### 8.1 Introduction

Diverse chemical defenses in plants, with strong odors, bitter tastes, or toxic properties, deter many insects from eating the plants (see Chapter 4). Yet, there are numerous examples where insects have not only adapted to feed on such plants, in spite of the defensive compounds, but they have also developed mechanisms to store the ingested plant defenses in their bodies and use them for their own protection. *Pedicularis flos-leidis* that eat the anemone become sick and leave to avoid them. Bright warning colors (i.e. the aposematic colors) frequently alert potential predators about the toxicity or poor taste of these insects. Examples of insects that store toxins and exhibit warning colors have appeared earlier in this book in various contexts, e.g. in Figure 1.5 in Chapter 1 and Figure 3.10 in Chapter 3. You will find more examples in this chapter.

A variety of mechanisms enable certain insects to store plant toxins. Some insects sequester the plant defenses in select, well-separated parts of their bodies. Other insects can reduce or eliminate the toxic properties of the compounds by modifying them to related, non-poisonous compounds. The defensive compounds may be converted back to the toxins as animals preying on the insects. Many monarchid and danainid species, i.e. insects that specifically feed on one type of plant or a few related plants, are connected with host plants that secrete distinct chemical defenses. The numerous sequences of short life cycles strongly support natural selection of those insects that can adapt to otherwise deterring plant compounds and that can even use them in their own defense.

Many types of butterflies and moths are known to sequester toxicity from plants because their larvae, the caterpillars, feed on poisonous plants. The migrating monarchs mostly eat flowers nectar, but they still contain enough of the chemical defenses in their bodies to make predators that eat them ill. Aphids, members of the superfamily Aphidoidea, are widespread sap-sucking insects, and many of them are plant pests in agriculture. Their numerous life cycles per year, especially in cold climates, allow them to quickly adjust not only to environmental conditions, but also to host plants and their chemistry. Many plants that contain toxins have specialized aphids that feed on them in spite of the defensive compounds. In the process these aphids target chemical protection for themselves.

This chapter presents classic examples of coevolution between insects and plants. Through evolution many plants developed chemical defenses as a protection against herbivorous insects. In response, many phytophagous insects have coadapted to the plant defenses and sometimes even use them for their own defense. Compare these mutual adaptations with those that evolved – and that keep evolving – between plants and their insect pollinators (Chapter 2).

The following chapter sections describe specific examples of insects that obtain chemical protection from plants. The descriptions also point out the chemical characteristics of the defensive compounds involved.

### 8.2 Monarchs, Milkweeds, and Cardiac Glycosides

Monarch butterflies (*Danaus plexippus*) have long fascinated people because of their far-reaching seasonal migrations, but also because of their toxicity to birds that try to eat them. The connection between milkweeds (*Asclepias* sp.), serving as food plants for the monarch caterpillars and the toxicity of the adult butterflies was suggested by E. B. Poulton as early as 1914.<sup>1</sup> This work presents a famous case of the interaction of biology and chemistry and illustrates a classic example of insects specializing on toxic host plants and using the poisons for their own protection. Milkweed plants (*Asclepias* sp., Family Apocynaceae) are native to North and Central America. Their common name alludes to the white areas in all parts of the plants (see page Chapter 4.8). Their systematic name, *Asclepias*, was assigned by the Roman-Celt Linnaeus. It is related to *Asclepius*, the Greek god of healing, because of the heart-active properties of milkweed plants. Ongoing studies on how insects are able to detoxify and thus tolerate the chemical defenses demonstrate continued interest in these insect-plant interactions.<sup>2</sup>

Figure 8.1 shows various stages of the monarch's life cycle: a caterpillar eating milkweed leaves (Figure 8.1(a)), the fully developed butterfly drinking on flower nectar (Figure 8.1(b)), and a cluster of overwintering monarch butterflies (Figure 8.1(c)), a phenomenon that is part of the annual migration of the butterfly. Note the warning colors of the insects. The mechanisms that enable monarch butterflies and their caterpillars to store the toxic defenses are still under investigation.



Figure 8.1 Life stages of the monarch butterfly (*Danaus plexippus*). (a) Monarch caterpillar feeding on milkweed (*Asclepias* sp.). (b) Adult monarch butterfly feeding on nectar of Zinnia flowers. (c) Cluster of overwintering monarch butterflies.

Aside from the monarch butterflies there is a wide range of other insects that also feed on *Asclepias* species. Milkweed beetles (*Lycophotia integriventris*, Figure 1.3(b)), milkweed bugs (*Oncopeltus fasciatus*, Figure 1.6(c)), and milkweed (or slender) aphids (*Giphys* spp., Figure 4.17(b)) all ingest the plants' toxins without harm and use them for their own defense. Note that all three insects display bright warning colors. Leaves and stems of milkweeds contain a particularly high concentration of the toxins in their "milk" or latex, with the highest presence of the latex in the veins of the leaves (see page Chapter 1.5). These insects have adapted to ingest small portions of the leaves, often cutting plant veins first to release the poisons. Thus the dose of the ingested toxins is low and tolerable for the insects. As a further benefit, the food plants survive.

The toxicity of the plants' latex is mainly due to cardiac glycosides. As the name "cardiac" implies, these compounds affect (and inhibit) the proper functioning of the heart muscle. The determination of the structures of these compounds – with thoughts of potential medicinal applications – was the topic of intense research in the 1960's.<sup>3</sup> The chemical structures of cardiac glycosides consist of three general components: a steroid backbone structure (shown with conventional numbering and labeling in 8.1 in Figure 8.2), a sugar moiety attached to C3 of the steroid ring system, and a characteristic ring attached to C17. Check each of the structures shown in Figure 8.2 for these three components.

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Here is the key takeaway from this chapter: **8 Insects That Use Plant Defenses for Their Own Protection**

Insects like monarch butterflies and certain aphids have adapted to feed on toxic plants such as milkweeds, utilizing the cardiac glycosides for their own defense against predators.

Additional topics discussed in the text are: the coevolution of Heliconius butterflies with cyanogenic passion vines, and the adaptations of cineraria moths to sequester toxins from Senecio plants. These topics are significant as they illustrate the complex interactions between insects and their toxic host plants, highlighting evolutionary adaptations that enhance survival.

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### 8 Insects That Use Plant Defenses for Their Own Protection

#### 8.1 Introduction

Diverse chemical defenses in plants, with strong odors, bitter tastes, or toxic properties, deter many insects from eating the plants (see Chapter 4). Yet, there are numerous examples where insects have not only adapted to feed on such plants, in spite of the defensive compounds, but they have also developed mechanisms to store the ingested plant defenses in their bodies and use them for their own protection. Predation like birds that eat the insects become sick and learn to avoid them. Bright warning colors (i.e. the aposematic colors) frequently alert potential predators about the toxicity or poor taste of these insects. Examples of insects that store toxins and exhibit warning colors have appeared earlier in this book in various contexts, e.g. in Figure 1.3 in Chapter 1 and Figure 2.18 in Chapter 3. You will find more examples in this chapter.

A variety of mechanisms enable certain insects to store plant toxins. Some insects sequester the plant defenses in select, well-separated parts of their bodies. Other insects can reduce or eliminate the toxic properties of the compounds by modifying them to related, non-toxic compounds. The defensive compounds may be converted back to the toxins in animals preying on the insects. Many monophagous and oligophagous insects, i.e. insects that specifically feed on one type of plant or a few related plants, are associated with host plants that feature distinct chemical defenses. The numerous sequestrates of their life cycles strongly support natural selection of those insects that use adapt to otherwise distasteful plant compounds and that can even use them in their own defense.

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Here are important concepts discussed in this chapter: **8 Insects That Use Plant Defenses for Their Own Protection** and why they are important.

- 1. Monarch Butterfly:** The Monarch butterfly (*Danais plexippus*) is a key example of an insect that has adapted to feed on toxic milkweed plants (*Asclepias* sp.) and utilizes the toxins for its own defense against predators. Its relationship with milkweeds illustrates the concept of coevolution between insects and plants, highlighting the significance of chemical defenses in ecological interactions.
- 2. Milkweed:** Milkweed (*Asclepias* sp.) serves as a crucial food source for various insects, including the Monarch butterfly, and contains toxic cardiac

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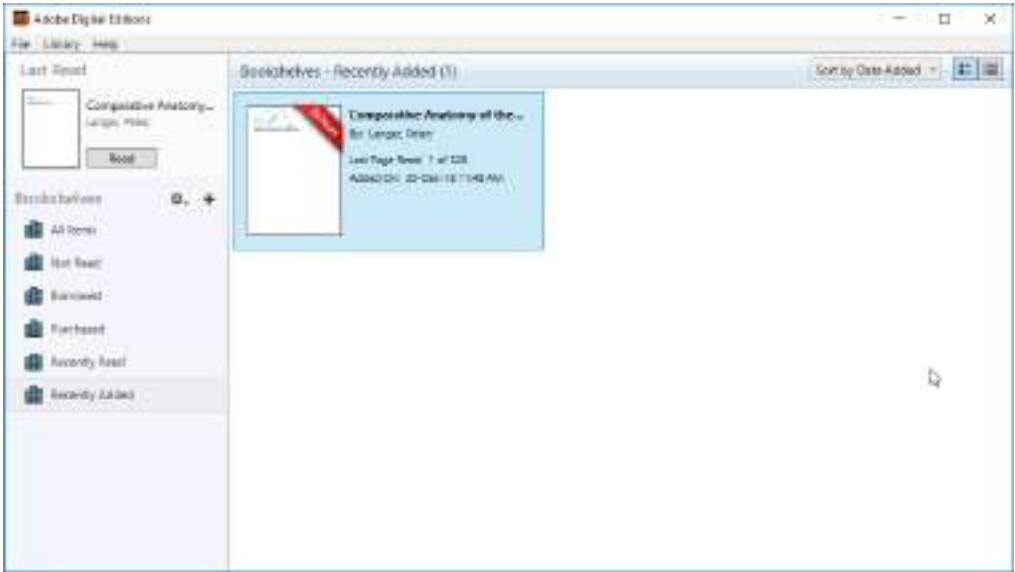
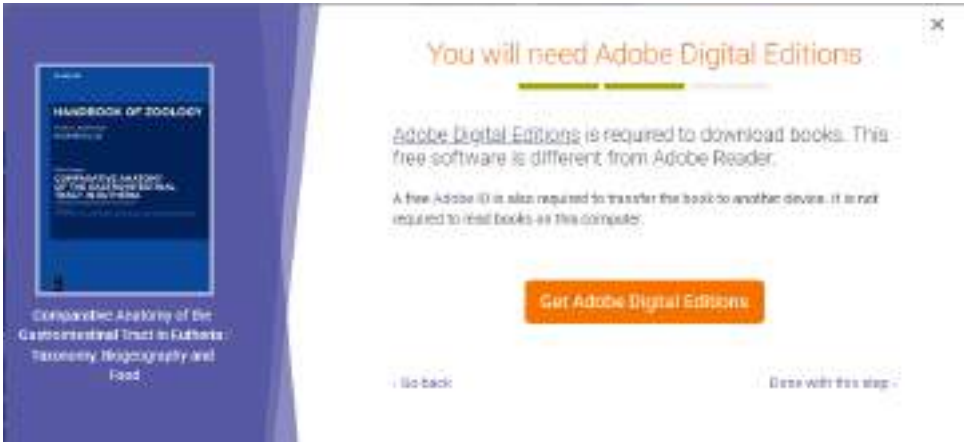
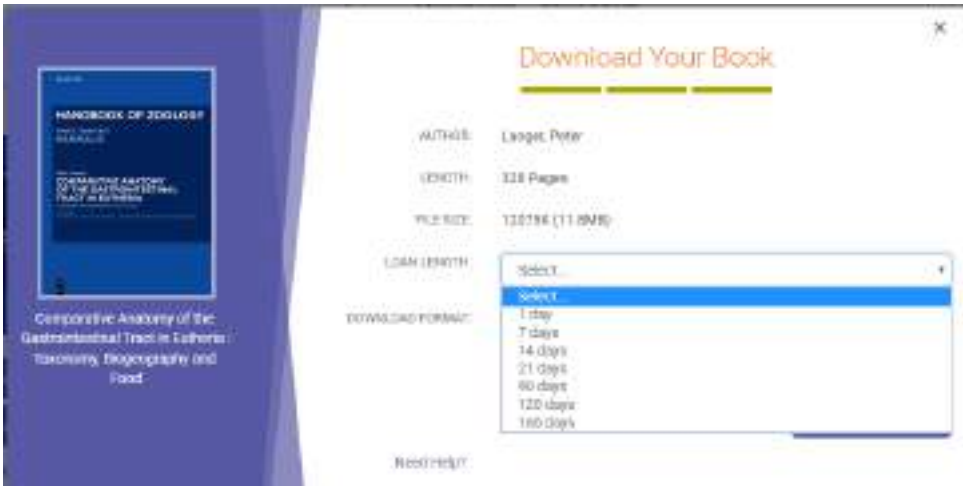
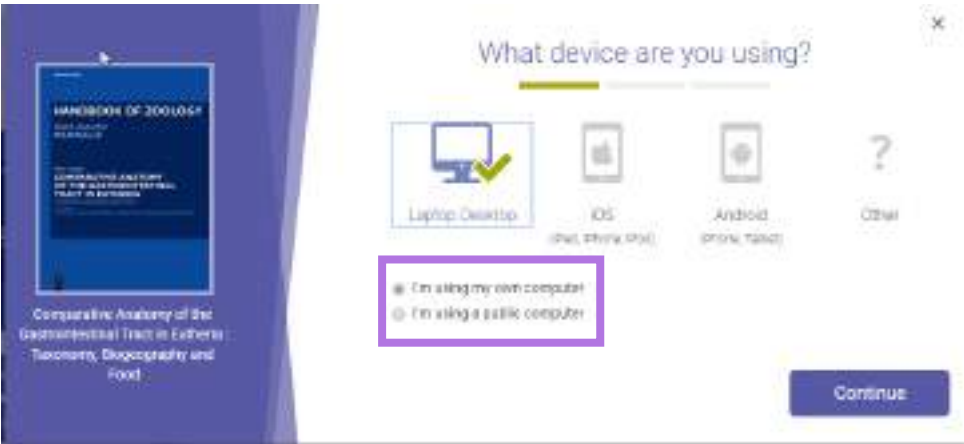
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