

Appendix II: Example of an outstanding outline composed by a Biol 515 student in Fall 2001. Note: This outline is not perfect and would earn ~ 46 points in the Scoring Rubric.

Topic: Nudibranch Defense Mechanisms

1. Introduction
 - 1.1 What are nudibranchs?
 - a. Taxonomy (Pearse and Buchsbaum 1987)
 - b. Location (Pearse and Buchsbaum 1987)
 - c. Description
 - i. Dorid nudibranchs (Pearse and Buchsbaum 1987)
 - ii. Eolid nudibranchs (Pearse and Buchsbaum 1987)
 - 1.2 Defense Strategies of Mollusca
 - a. Brief overview of diversity of Molluscan defense (Pearse and Buchsbaum 1987)
 - b. Nudibranch defense overview
 - 1.3 Evolution of Nudibranch defense
 - a. Reason for loss of shell (Cronin 1995)
 - b. Diet derived defense strategy (Pawlik 1988)
 - c. Self derived defense strategy (García-Gómez 1990)
 - 1.4 Main topic: This paper will discuss how different species of nudibranchs use defense chemicals in combination with other defense mechanisms to create a strong anti-predator defense strategy. First, we will discuss the cnidarian eating nudibranchs. Then, we will discuss the sponge eating nudibranchs. And finally, we will discuss the nudibranchs who synthesize their own defense chemicals.
2. Cnidarian eating nudibranchs
 - 2.1 *Tritoniella belli*
 - a. Type of nudibranch (Bryan 1998)
 - b. Type of cnidarian it feeds on (Bryan 1998)
 - c. Types of predators (McClintock 1994)
 - d. Means of defense (Bryan 1998)
 - i. Chemical
 - ii. Other
 - e. Experimentation of chemicals (Bryan 1998)
 - 2.2 *Hexabanchus sanguineus*
 - a. Type of nudibranch (Pawlik 1988)
 - b. Type of cnidarian it feeds on (Pawlik 1988)
 - c. Types of predators (Pawlik 1988)
 - d. Means of defense (Pawlik 1988)
 - i. Chemical
 - ii. Coloration
 - iii. Eggs
 - e. Discussion as to why concentration of chemical near the gonads and coloration work together to fulfill the nudibranchs defensive needs.
 - 2.3 *Tritonia hamnerorum*
 - a. Type of nudibranch (Cronin 1995)
 - b. Type of cnidarian it feeds on (Cronin 1995)
 - c. Type of predators (Cronin 1995)
 - d. Means of defense (Cronin 1995)
 - i. Chemical
 - ii. Nematocysts
 - e. Experimentation of chemicals (Cronin 1995)
 - f. Discussion of why there are so many different types of chemicals and chemical concentrations found in nudibranchs (Cronin 1995, Faulkner 1983)

- 2.4 *Phyllodesmium guamensis*
 - a. Type of nudibranch (Slattery 1998)
 - b. Type of cnidarian it feeds on (Slattery 1998)
 - c. Type of predators (Slattery 1998)
 - d. Means of defense (Slattery 1998)
 - i. Chemical
 - ii. Detachable cerata
 - e. Improving on defense strategies
3. Sponge eating nudibranch
 - 3.1 *Glossodoris valenciennes* and *Glossodoris tricolor*
 - a. Type of nudibranch (Cimino 1982)
 - b. Type of sponge it feeds on (Cimino 1982)
 - c. Type of predators (Cimino 1982)
 - d. Means of defense (Cimino 1982)
 - i. Chemical
 - ii. Ability to change sequestered chemical
 - 3.2 *Rostanga pulchura*
 - a. Type of nudibranch (Faulkner 1983)
 - b. Type of sponge it feeds on (Faulkner 1983)
 - c. Type of predators (Faulkner 1983)
 - d. Means of defense (Faulkner 1983)
 - i. Chemical
 - ii. Localized chemical storage
 - iii. Pigment
 - e. Discussion of enhanced defense system
 - 3.3 *Glossodoris palladi*
 - a. Type of nudibranch (Rogers 1991)
 - b. Type of sponge it feeds on (Rogers 1991)
 - c. Type of predators (Rogers 1991)
 - d. Means of defense (Rogers 1991)
 - i. Chemical
 - ii. Coloration
 - 3.4 *Hypselodris* sp.
 - a. Type of nudibranch (García-Gómez 1990)
 - b. Type of sponge it feeds on (García-Gómez 1990)
 - c. Type of predators (García-Gómez 1990)
 - d. Means of defense (García-Gómez 1990)
 - i. Chemical
 - ii. MDFs
 - e. Discussion of MDFs and why they may help the nudibranch better than having the defensive chemicals spread all around
4. Nudibranchs who synthesize their own defense chemicals
 - 4.1 *Bathydoris hodgsoni*
 - a. Type of nudibranch (Avila 2000)
 - b. Type of predators (Avila 2000)
 - c. Means of defense (Avila 2000)
 - i. de novo synthesis of chemical
 - ii. detachable papillae
 - 4.2 *Austrodoris kerguelensis*
 - a. Type of nudibranch (Davies-Coleman 1991)

- b. What it feeds on (Davies-Coleman 1991)
- c. Type of predators (Davies-Coleman 1991)
- d. Means of defense (Davies-Coleman 1991)
 - i. Chemical
- 4.3 Discussion on de novo synthesis and why it might be a step up from dietarily derived acquisition
- 5. Conclusion
 - 5.1 Review of different chemicals and other defense mechanisms
 - 5.2 Discussion of why there are so many different chemicals
 - 5.3 Explanation, or belief, on why some nudibranchs use de novo synthesis instead of sequestering chemicals from prey.
 - 5.4 Future ideas on studying nudibranch defense mechanisms

Literature Cited (*note*: in the Literature Cited, all authors' names should be listed, rather than using "et al."; see *Ecology*)

- Avila, C., et al. 2000. Chemical ecology of the Antarctic nudibranch *Bathydoris hodgsoni* Eliot, 1907: defensive role and origin of its natural products. *Journal of Experimental Marine Biology and Ecology* **252**:27-44.
- Bryan, P. J., J. B. McClintock, and B. J. Baker. 1998. Population biology and antipredator defenses of the shallow-water Antarctic nudibranch *Tritoniella belli*. *Marine Biology* **132**:259-265.
- Cimino, G., et al. 1982. The chemical defense of four Mediterranean nudibranchs. *Comp. Biochem. Physiol.* **73**:471-474.
- Cronin, G., et al. 1995. Distribution, density, and sequestration of host chemical defenses by the specialist nudibranch *Tritonia hamnerorum* found at high densities on the sea fan *Gorgonia ventalina*. *Marine Ecology – Progress Series* **119**:177-189.
- Davies-Coleman, M. T., and D. J. Faulkner. 1991. New diterpenoic acidglycerides from the Antarctic nudibranch *Austrodoris kerguelensis*. *Tetrahedron* **47**:9743-9750.
- Faulkner, D. J., and M. T. Ghiselin. 1983. Chemical defense and evolutionary ecology of dorid nudibranchs and some other opisthobranch gastropods. *Marine Ecology – Progress Series* **13**:295-301.
- García-Gómez, J. C., G. Cimino, and A. Medina. 1990. Studies on the defensive behaviour of *Hypselodoris* species (Gastropoda: Nudibranchia): ultrastructure and chemical analysis of mantle dermal formations (MDFs). *Marine Biology* **160**:245-250.
- McClintock, J. B., et al. 1994. Chemical defense of common Antarctic shallow-water nudibranch *Tritoniella belli* Eliot (Mollusca: Tritonidae) and its prey, *Clavularia frankliniana* Rouel (Cnidaria: Octocorallia). *Journal of Chemical Ecology* **20**:3361-3371.
- Pawlik, J. R., et al. 1988. Defensive chemicals of the Spanish dancer nudibranch *Hexabanchus sanguineus* and its egg ribbons: macrolides derived from a sponge diet. *Journal of Experimental Marine Biology and Ecology* **119**:99-109.
- Pearse, V., et al. 1987. *Living Vertebrates*. The Boxwood Press, Pacific Grove, California, USA.
- Slattery, M., et al. 1998. A sequestered soft coral diterpene in the aeolid nudibranch *Phyllodesmium guamensis* Avila, Ballesteros Slattery, Starmer and Paul. *Journal of Experimental Marine Biology and Ecology* **266**:33-49.