# Supplemental Material

*CBE—Life Sciences Education*

Driessen *et al*.

**Supplemental Materials**

**Contents:**



**Appendix A:** Instructor Interview Questions

1. Can you start by telling me your definitions of sex and gender?
2. What knowledge or resources did you seek out when constructing these course materials?
    a. [Follow-up]: Feel free to reflect broadly on the resources you used when developing all sex and gender content for your course.
    b. [Follow-up]: Did you use any resources outside of biology content? For example, resources beyond biology textbooks and publications, such as work from gender studies or popular press?
3. What knowledge or resources were particularly helpful for you when constructing these course materials?
4. What knowledge or resources did you have trouble finding, if any, when constructing these course materials?
5. What topics or ideas felt especially difficult to teach through your course materials? Feel free to reference the examples provided or related course topics.
6. What were your goals when teaching sex and gender?
7. How, if at all, were you concerned with how students would perceive these course materials? Feel free to reference any of these specific materials if it helps you explain.
8. How, if at all, were you concerned with how your peers or others would perceive these course materials?
9. How, if at all, were you concerned with the experiences of students when constructing these materials?
    a. [Follow-up]: Were you concerned about the experiences of TNG students when constructing these materials? If so, can you tell me more about why you were concerned and how that impacted your pedagogical choices?
10. Thinking back to when you last taught with these materials, did you notice any student reactions or responses that were interesting or surprising to you?
11. How, if at all, do you consider these course materials to be more or less inclusive of TNG students? (Skip this question if it is answered in the question prior.)
12. Do you believe your approach to teaching sex and gender may differentially impact students in the classroom? If so, how?
13. What aspects of these course materials would you consider changing in the future and why?

a. [Follow-up]: Can you walk me through how, if at all, you would change each of these example materials and why?

14. Is there anything else you want to share with us about teaching these materials?

**Appendix B:** The Complexities of Sex-Related Language in Biology

Because of this history of how the term hermaphrodite has been used in humans, some have called for replacing the term. However, a simple language replacement does not exist. Additionally, even if there were a term we could use to immediately replace the term hermaphrodite, an understanding of this term would be necessary to understand already existing literature. Given the complexity around this word instructors may need to think deliberately about their approach to it and knowing more about the language used in biology to describe sex across organisms may be useful.

It is beyond the scope of this supplement to delve deeply into the language around sex and reproduction. We encourage those interested in a deeper dive to read texts such as Leonard (2018), Beukeboom and Perin (2014), and the impressively still relevant 4th edition of *A Glossary of Botanic Terms* (Jackson, 1928). We also encourage readers to delve into the literature about the diversity of organisms that produce other types of gametes beyond eggs and sperm or reproduce without gametes, as these are also important in broader discussions around sex and reproduction, as well as the specifics of reproduction in unicellular organisms (see Billiard et al., 2011; Constable & Kokko, 2018, 2021; Heitman et al., 2007; Kratochvíl et al., 2020; Wallen & Perlin, 2018; Wiese, 1981; Wiese et al., 1979).

Across the diversity of life there are many ways that gamete production and the associated related structures are organized within individuals, and the language currently used in western modern science to describe these is complex. The terms hermaphroditic and gonochoric can be used to characterize a wide variety of organisms, including plants and animals, and there are many terms that exist to describe different types of hermaphroditic organisms (Ainsworth et al., 2005; Jabbour et al., 2022; Leonard, 2018). It is important to caution regarding the use of terms that seemingly provide an easy substitute for the term hermaphrodite in all its sequential and simultaneous complexity. Gamete organization is diverse across the breadth of bigametic[1] species (those that produce two types of gametes; the term bigametic does not provide any information about how those two types of gametes are organized in individuals) (Ranta et al., 1999; Vicent et al., 2014).

The language that exists to describe is complex, and oversimplification of this language can create confusion. To provide one example, the terms monoecious, dioecious, trioecious, and synecious provide linguistic tools to differentiate gamete organization within species and include some of the more common language used to describe gamete organization. The term dioecious

[1] The term bigametic (or bi-gametic) has two very different meanings in the technical biology literature. As referenced in the main text, bigametic can be used to describe any species that produces two different types of gametes (Ranta et al., 1999; Vicent et al., 2014). However, it is also used in organisms with haplo-diploid sex determination, such as bees, to describe offspring that are either unigametic (from an unfertilized egg) or bigametic (from a fertilized egg) (Hagedoorn, 1909).

describes species where an individual typically produces only eggs or sperm; however, intersex individuals in gonochoric species may have a combination of characteristics typical of individuals who produce eggs and those who produce sperm (Beukeboom & Perrin, 2014). Thus, gonochoric species are dioecious. In contrast, monoecious, trioecious, and synecious refer to different types of hermaphroditic species. Trioecious species have three different types of individuals, ones that produce eggs, ones that produce sperm, and ones that produce both eggs and sperm (Beukeboom & Perrin, 2014; Jackson, 1928). Monoecious and synecious species are most easily described using flowering plants as an example, and are generally used as botanical terms (Jackson, 1928). A monoecious flowering plant produces two types of flowers, both flowers that only produce eggs and flowers that only produce sperm (Beukeboom & Perrin, 2014; Jackson, 1928). In contrast, a synecious flowering plant produces only one type of flowers, flowers that each individually produce both eggs and sperm (Jackson, 1928).

The above paragraph provides only a few examples. The range of hermaphroditic reproductive systems that exist are complex, and as such there are a plethora of terms used to describe this diversity, and there are ongoing discussions in different fields of biology to improve this language (e.g., Avise & Mank, 2009; Beukeboom & Perrin, 2014; Coelho et al., 2018; Cossard et al., 2022; Diggle, 2023; Jabbour et al., 2022; Jackson, 1928; Lloyd, 1980; Maciel-Silva & Porto, 2016; Oberle & Fairchild, 2023; Pannell, 2023; Subramaniam & Bartlett, 2023). While engaging in this complexity can be challenging, this language complexity allows for the description of the amazing biological diversity that exists.

**S1 Table**. Table of Instructor Resources for Unlearning Gender Essentialism with Links

| Resource Reference | Type | Topic | Resource Link |
|---|---|---|---|
| Andrzejewski et al. (2019) | Article | Collaborative Unlearning | https://doi.org/10.1080/10714413.2019.1694358 |
| Bonetta & Julian (2018) | Activity | *Sex verification of athletes*. | https://media.hhmi.org/biointeractive/click/testing-athletes/introduction.html |
| Casper et al. (2022) | Article | Gender Essentialism Harms Students with Queer Genders in Undergraduate Biology | https://doi.org/10.1187/cbe.21-12-0343 |
| Fausto-Sterling (2012) | Book | Sex/Gender in Biology | https://doi.org/10.4324/9780203127971 |
| Hales (2020) | Article | Inclusive Sex and Gender Teaching in Genetics | https://doi.org/10.1187/cbe.19-08-0156 |
| Hubbard & Monnig (2020) | Article | Inclusive Sex and Gender Teaching in Genetics | https://doi.org/10.1007/s11191-020-00164-0 |
| McLeod et al. (2020) | Article | Collaborative Unlearning | https://doi.org/10.1080/14623943.2020.1730782 |
| Saini & Ah-King (2023) | Podcast | Reframing sex perspectives in ecology to be more inclusive | https://www.science.org/content/podcast/talking-tongues-detecting-beer-and-shifting-perspectives-females |
| Stuhlsatz, Buck Bracey, & Donovan (2020) | Article | A study on student conflation of sex and gender in 8$^{th}$ -10$^{th}$ grade genetics | https://doi.org/10.1007/s11191-020-00177-9 |
| Zemenick et al (2022a) | Article | Inclusive Sex and Gender Teaching in Biology | https://doi.org/10.1093/biosci/biac013 |

**Supplemental Material References:**


Ainsworth, C., Rahman, A., Parker, J., & Edwards, G. (2005). Intersex inflorescences of *Rumex acetosa* demonstrate that sex determination is unique to each flower. *New Phytologist*, *165*(3), 711–720. https://doi.org/10.1111/j.1469-8137.2005.01281.x

Andrzejewski, C. E., Baker-Doyle, K. J., Glazier, J. A., & Reimer, K. E. (2019). (Re) framing vulnerability as social justice work: Lessons from hacking our teacher education practices. *Review of Education, Pedagogy, and Cultural Studies*, *41*(4-5), 317-351.

Avise, J. C., & Mank, J. E. (2009). Evolutionary Perspectives on Hermaphroditism in Fishes. *Sexual Development*, *3*(2–3), 152–163. https://doi.org/10.1159/000223079

Beukeboom, L. W., & Perrin, N. (2014). *The evolution of sex determination* (1st ed). Oxford university press.

Billiard, S., López-Villavicencio, M., Devier, B., Hood, M. E., Fairhead, C., & Giraud, T. (2011). Having sex, yes, but with whom? Inferences from fungi on the evolution of anisogamy and mating types. *Biological Reviews*, *86*(2), 421–442. https://doi.org/10.1111/j.1469-185X.2010.00153.x

Bonetta, L., & Julian, D. (2018, October 24). *Sex verification of athletes*. Sex Verification of Athletes. https://media.hhmi.org/biointeractive/click/testing-athletes/introduction.html

Casper, A. A., Rebolledo, N., Lane, A. K., Jude, L., & Eddy, S. L. (2022). "It's completely erasure": A Qualitative Exploration of Experiences of Transgender, Nonbinary, Gender Nonconforming, and Questioning Students in Biology Courses. CBE—Life Sciences Education, 21(4), ar69.

Coelho, S. M., Gueno, J., Lipinska, A. P., Cock, J. M., & Umen, J. G. (2018). UV Chromosomes and Haploid Sexual Systems. *Trends in Plant Science*, *23*(9), 794–807. https://doi.org/10.1016/j.tplants.2018.06.005

Constable, G. W. A., & Kokko, H. (2018). The rate of facultative sex governs the number of expected mating types in isogamous species. *Nature Ecology & Evolution*, *2*(7), 1168–1175. https://doi.org/10.1038/s41559-018-0580-9

Constable, G. W. A., & Kokko, H. (2021). Parthenogenesis and the Evolution of Anisogamy. *Cells*, *10*(9), 2467. https://doi.org/10.3390/cells10092467

Cossard, G. G., Godfroy, O., Nehr, Z., Cruaud, C., Cock, J. M., Lipinska, A. P., & Coelho, S. M. (2022). Selection drives convergent gene expression changes during transitions to co-sexuality in haploid sexual systems. *Nature Ecology & Evolution*, *6*(5), 579–589. https://doi.org/10.1038/s41559-022-01692-4

Diggle, P. K. (2023). On the meaning and use of "gender" and "sex" in plant biology. *American Journal of Botany*, *110*(7), e16205. https://doi.org/10.1002/ajb2.16205

Fausto-Sterling, A. (2012). *Sex/gender: Biology in a social world*. Routledge.

Hagedoorn, A. L. (1909). Mendelian inheritance of sex. *Archiv Für Entwicklungsmechanik Der Organismen*, *28*(1), 1–34. https://doi.org/10.1007/BF02289897

Hales, K. G. (2020). Signaling inclusivity in undergraduate biology courses through deliberate framing of genetics topics relevant to gender identity, disability, and race. CBE—Life Sciences Education, 19(2), es2

Heitman, J., Kronstad, J. W., Taylor, J. W., & Casselton, L. A. (Eds.). (2007). *Sex in Fungi: Molecular Determination and Evolutionary Implications*. ASM Press. https://doi.org/10.1128/9781555815837

Hubbard, A. R., & Monnig, L. A. (2020). Using Anthropological Principles to Transform the Teaching of Human "Difference" and Genetic Variation in College Classrooms. Science & Education, 29(6), 1541–1565. https://doi.org/10.1007/s11191-020-00164-0

Jabbour, F., Espinosa, F., Dejonghe, Q., & Le Péchon, T. (2022). Development and Evolution of Unisexual Flowers: A Review. *Plants*, *11*(2), 155. https://doi.org/10.3390/plants11020155

Jackson, B. D. (1928). *A glossary of botanic terms with their derivation and accent* (4th ed.). Gerald Duckworth & Co. LTD.; Harper Publishing Co. Inc.

Kratochvíl, L., Vukić, J., Červenka, J., Kubička, L., Johnson Pokorná, M., Kukačková, D., Rovatsos, M., & Piálek, L. (2020). Mixed‐sex offspring produced via cryptic parthenogenesis in a lizard. *Molecular Ecology*, *29*(21), 4118–4127. https://doi.org/10.1111/mec.15617

Leonard, J. L. (Ed.). (2018). *Transitions Between Sexual Systems: Understanding the Mechanisms of, and Pathways Between, Dioecy, Hermaphroditism and Other Sexual Systems*. Springer International Publishing. https://doi.org/10.1007/978-3-319-94139-4

Lloyd, D. G. (1980). Sexual strategies in plants III. A quantitative method for describing the gender of plants. *New Zealand Journal of Botany*, *18*(1), 103–108. https://doi.org/10.1080/0028825X.1980.10427235

Maciel-Silva, A. S., & Porto, K. C. (2016). Reproduction in Bryophytes. In K. G. Ramawat, J.-M. Merillon, & K. R. Shivanna (Eds.), *Reproductive Biology of Plants* (pp. 57–84). CRC Press. https://doi.org/10.1201/b16535-15

McLeod, K., Thakchoe, S., Hunter, M. A., Vincent, K., Baltra-Ulloa, A. J., & MacDonald, A. (2020). Principles for a pedagogy of unlearning. *Reflective Practice*, *21*(2), 183-197.

Oberle, B., & Fairchild, E. (2023). On the benefits of clarifying the meaning of "plant gender." *American Journal of Botany*, *110*(7), e16196. https://doi.org/10.1002/ajb2.16196

Pannell, J. R. (2023). Sex, sexes, sex roles, and gender in land plants. *American Journal of Botany*, *110*(7), e16195. https://doi.org/10.1002/ajb2.16195

Ranta, E., Kaitala, V., & Lindström, J. (1999). Sex in space: Population dynamic consequences. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *266*(1424), 1155–1160. https://doi.org/10.1098/rspb.1999.0757

Saini, A., Ah-King, M. (2023). *Talking tongues, detecting beer, and shifting perspectives on females*. Science.

https://www.science.org/content/podcast/talking-tongues-detecting-beer-and-shifting-perspectives-females

Stuhlsatz, M. A. M., Buck Bracey, Z. E., & Donovan, B. M. (2020). Investigating Conflation of Sex and Gender Language in Student Writing About Genetics. Science & Education, 29(6), 1567–1594. https://doi.org/10.1007/s11191-020-00177-9

Subramaniam, B., & Bartlett, M. (2023). Re-imagining Reproduction: The Queer Possibilities of Plants. *Integrative And Comparative Biology*, *63*(4), 946–959. https://doi.org/10.1093/icb/icad012

Vicent, M., Gabriel Y Galán, J. M., & Ainoüche, A. (2014). Profundizando en la evolución de los helechos: Un enfoque mecanicista a los principales conceptos y técnicas de estudio. *Botanica Complutensis*, *38*(0), 7–24. https://doi.org/10.5209/rev_BOCM.2014.v38.45771

Wallen, R. M., & Perlin, M. H. (2018). An Overview of the Function and Maintenance of Sexual Reproduction in Dikaryotic Fungi. *Frontiers in Microbiology*, *9*, 503. https://doi.org/10.3389/fmicb.2018.00503

Wiese, L. (1981). On the evolution of anisogamy from isogamous monoecy and on the origin of sex. *Journal of Theoretical Biology*, *89*(4), 573–580. https://doi.org/10.1016/0022-5193(81)90029-1

Wiese, L., Wiese, W., & Edwards, D. A. (1979). Inducible Anisogamy and the Evolution of Oogamy from Isogamy. *Annals of Botany*, *44*(2), 131–139. https://doi.org/10.1093/oxfordjournals.aob.a085712

Zemenick, A. T., Turney, S., Webster, A. J., Jones, S. C., & Weber, M. G. (2022). Six principles for embracing gender and sexual diversity in postsecondary biology classrooms. *BioScience*, *72*(5), 481-492.