Non-obvious controls:

- Be sure to try all the different tabs at the top of the simulation.
- You can change the **sample atom**. Each type of atomic nucleus has a different magnetic moment and thus a different energy splitting between the spin down and spin up state for the same **magnetic field**.
- To excite the nuclei, you must turn on the **radio wave source** and tune the **frequency** of the radio waves to match the excitation frequency between the spin down and spin up states. This excitation frequency depends on the **magnetic field**.
- In the second tab, you can excite the nuclei in one small region by adjusting the **horizontal** and **vertical gradients**.
- You can **Pause** the sim and then use **Step** to incrementally analyze.
- If you are doing a lecture demonstration, set your screen resolution to 1024x768 so the simulation will fill the screen and be seen easily.

Important modeling notes / simplifications:

- This simulation is based on the model of MRI presented in Louis Bloomfield's textbook, *How Things Work*.[1]

Insights into student use / thinking:

- We recommend starting with the first tab to help students learn the basic ideas of how to excite nuclei with a constant magnetic field. The second tab can be overwhelming if it is the first thing students see.
- In interviews, we found that even students with no science background were able to figure out the basics of how an MRI works by playing with this simulation.

Suggestions for sim use:

- For tips on using PhET sims with your students see: **Guidelines for Inquiry Contributions** and **Using PhET Sims**
- The simulations have been used successfully with homework, lectures, in-class activities, or lab activities. Use them for introduction to concepts, learning new concepts, reinforcement of concepts, as visual aids for interactive demonstrations, or with in-class clicker questions. To read more, see **Teaching Physics using PhET Simulations**
- For activities and lesson plans written by the PhET team and other teachers, see: **Teacher Ideas & Activities**
- Use MRI as a context for helping students understand magnetic moments, spin, and energy splitting between spin states.
- Ask students to calculate what **frequency** should excite the nuclei for a given **magnetic field** or vice versa, and use the simulation to check their calculations.
- Give students a table of magnetic moments for different atoms, and ask them to use the simulation to determine the mystery **sample atom** (marked "???").
- Turn off **Show atomic nuclei**, then **add tumor**, and ask students to determine where the tumor is by tuning the **frequency** to match the energy splitting and seeing where the most photons are emitted.

[1] L. Bloomfield, *How Things Work: The Physics of Everyday Life*, Wiley (2006), pp. 526-527.