How to cook meat

Preparing a piece of meat is no piece of cake, according to Harold McGee, Jack McInerney and Alain Harrus. Two of them are physicists and the other writes about the science of food and cooking. As far back as 1999, they published an article in the magazine *Physics Today* about the physics of cooking meat. In case you missed out on that, here are the juicy bits.

The tricky part of cooking meat? It is that time when the meat is just right, at just the right temperature, because it lasts only about two minutes. And how do you avoid overcooking the outer parts? The three abovementioned authors looked into the matter and came up with the following guidelines.

- Use thin cuts.
- Pre-warm the meat, for instance by immersing the (wrapped) meat in warm water, so that its temperature rises to about 40 °C (104 °F).
  This diminishes overcooking of the outer parts as it reduces the cooking time. Letting the meat warm to room temperature is much less effective!
  When you try this at home, you may notice that the color of the meat changes. The red color of meat is caused by myoglobin, an oxygen-storing protein. It denatures – breaks down - at higher temperatures and then turns grayish brown.
  Experiment with this and you may be pleasantly surprised by the results.
- Keep the surface temperature below boiling.
  This minimizes the temperature gradient across the meat and it maximizes the time interval during which the center of the meat is close to its temperature optimum.
- If you fry or grill meat: Flip the meat frequently. This is much gentler on the meat.
- Do not boil tender meats or fish. Simmering or poaching well below boiling is much better (at about 80 °C).
- Do not stick to standard rules about cooking time per weight or thickness. They have nothing to do with physics and cooking meat is physics, and chemistry. When you have double the thickness of a cut of meat, for instance, the cooking time does not become twice as much but almost four times as much.
  That's Fourier's Law at work. The rate of heat flow in one dimension is proportional to the square of the thickness.
- Remember the two-minute interval, when the meat is at its best. Most meat is properly done at temperatures between roughly 55 and 70 °C (130 to 160 °F). Most people cook meat to much higher temperatures, but only tough meats should be heated past 70 °C. Other meats turn very dry at those high temperatures.
- At 70 °C (160 °F), *E. coli* is destroyed. Browning, however, may already occur at lower temperatures and therefore is not a great indicator of temperature.

How to cook meat – continued

Heat transfer, that is what cooking is all about. Heat transfer comes in three kinds: conduction, convection and radiation. How the heat is transferred depends on whether the meat goes into an oven, a stewpot, a frying pan or a steamer. Heat transfer within the meat itself takes place mainly by conduction, however.

So, in summary, what determines how good your steak is going to taste?

- The difference between the temperature of the meat and the temperature of the heating source. It is the reason why heat goes into the meat, just like water flows downstream, not upstream.
- The type of meat. How good it is (its texture, and whether it has inhomogeneities).
- The temperature of everything in your kitchen and the initial temperature of the meat.
- The presence of water, which lowers the effective cooking temperature. Regular meat consists of about 75 weight percent water. If you think that loss of water has something to do with juiciness, you guessed right.
- The heating path. That's the time a piece of meat spends at a particular temperature. Or in plain English: how quickly or slowly you heat it and the way you turn up or turn down the heat when cooking your meat.

After reading the above, you may decide to spend a few bucks on a meat thermometer. Meat thermometers are not very expensive, and you can order one online from companies like Amazon.

The authors of the article in *Physics Today* used a computer program called FlexPDE to model their meat questions. You can download the Original Unlimited Scripted Multi-Physics Finite Element Solution Environment for Partial Differential Equations from the web site of PDE Solutions Inc. The magazine *Physics Today* is published by the American Institute of Physics.
