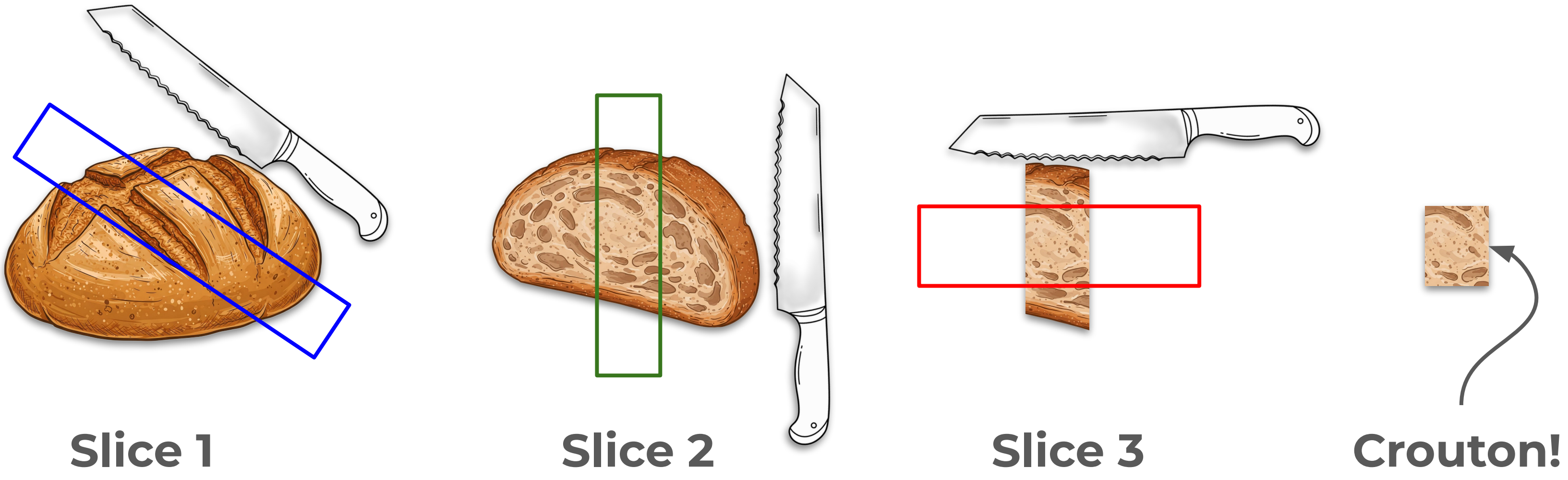
What is ‘Voxel Selection’?

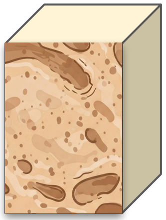
A brief primer

Picture a loaf of bread. You want to make croutons with it...



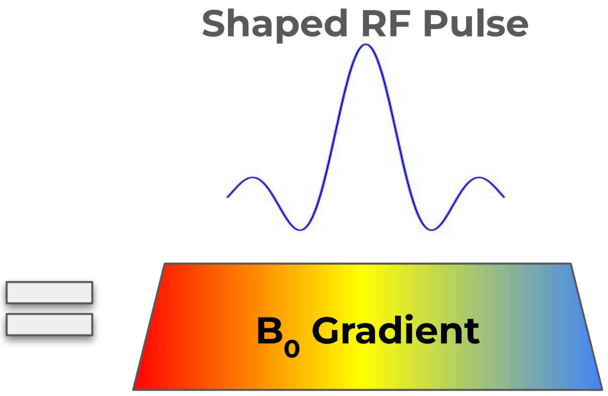
You need to subsequent slices along **3 different axes** to get that perfect cube for toasting!

In NMR spectroscopy, the crouton represents a 'voxel'



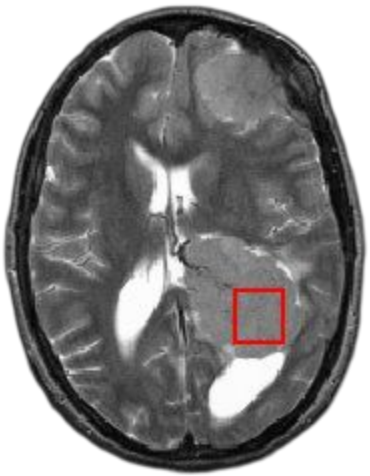
A **voxel** is a 3D volume within the sample from which NMR signals are acquired.

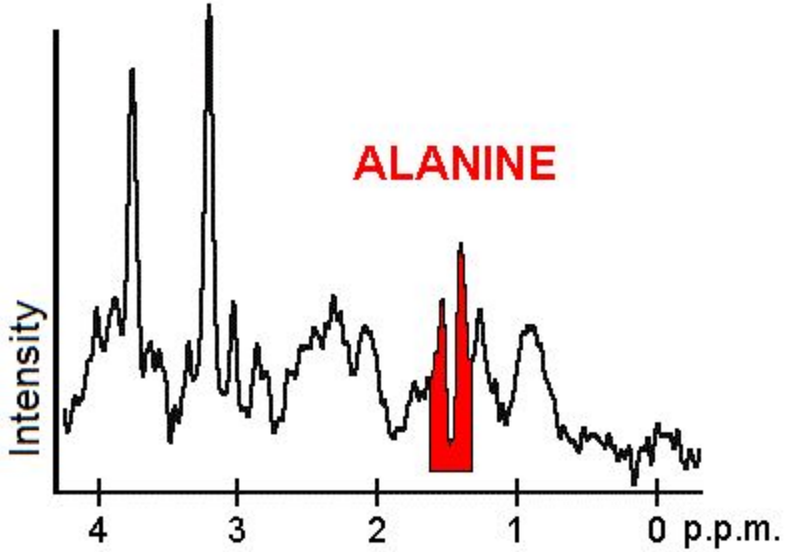
Instead of a knife to make the slices, we use **shaped RF pulses** and **pulsed field gradients**.



Why is voxel selection necessary for *in vivo* MRS?

Human body parts are extremely inhomogeneous, with different types of tissues of varying magnetic susceptibility. In order to acquire well resolved NMR signals, it is necessary to focus on a small, relatively homogeneous region.





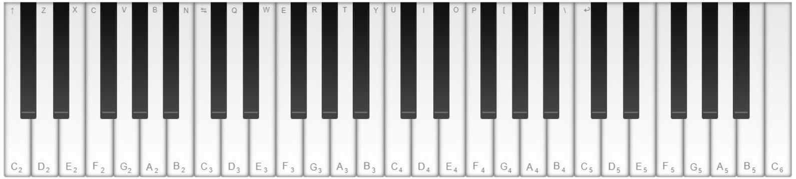
https://en.wikipedia.org/wiki/In_vivo_magnetic_resonance_spectroscopy#

What is a B_0 Gradient?

A **B_0 (magnetic field) gradient** encodes spatial position as a frequency.

Low frequencies

High frequencies



Just like how the frequency changes with position on a piano...

$B_0 - r_{max}G$ B_0 $B_0 + r_{max}G$

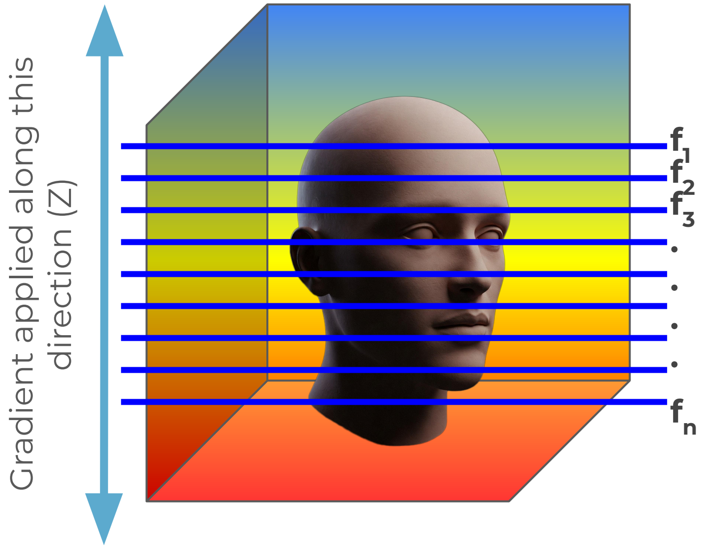
...frequency changes with position inside the magnet when a **B_0 gradient** is applied, because frequency is proportional to magnetic field.

If you know the frequency, you know where the signal is coming from!

How does a gradient ‘spatially encode’ frequency?

Frequency is related to magnetic field by: $f = (\gamma/2\pi)B_0$, γ being the gyromagnetic ratio

G_z (milliTesla/metre)



When magnetic field has a spatial dependence…

$$B(z) = B_0 + zG_z$$

Position

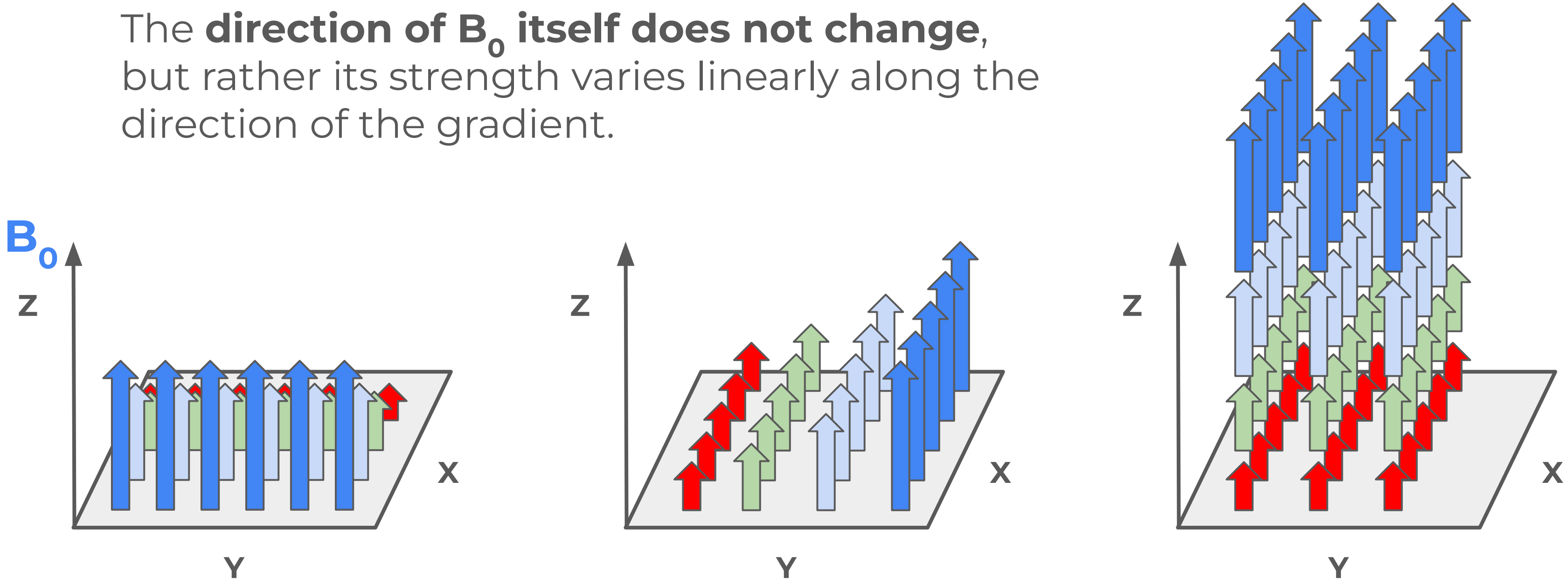
Multiply by γ

…frequency also has a position dependence:

$$f(z) = f_0 + (\gamma/2\pi)zG_z$$

B_0 Gradients can be applied along 3 orthogonal directions

The **direction of B_0 itself does not change**, but rather its strength varies linearly along the direction of the gradient.

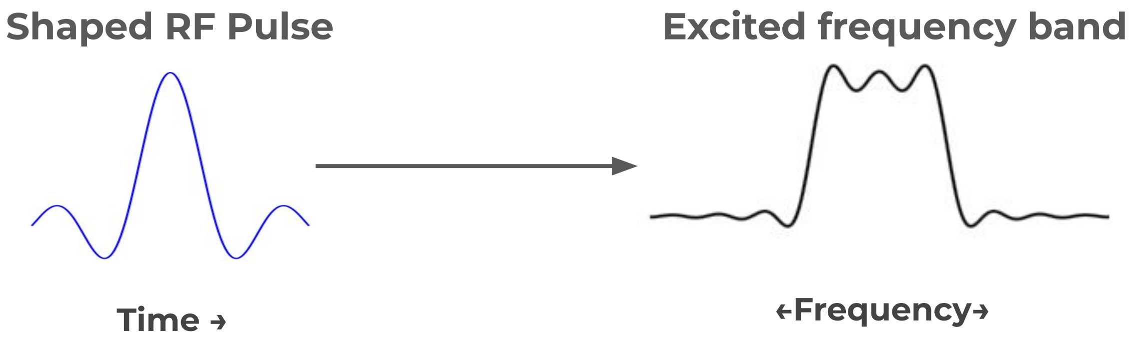


X - gradient **Y - gradient** **Z - gradient**

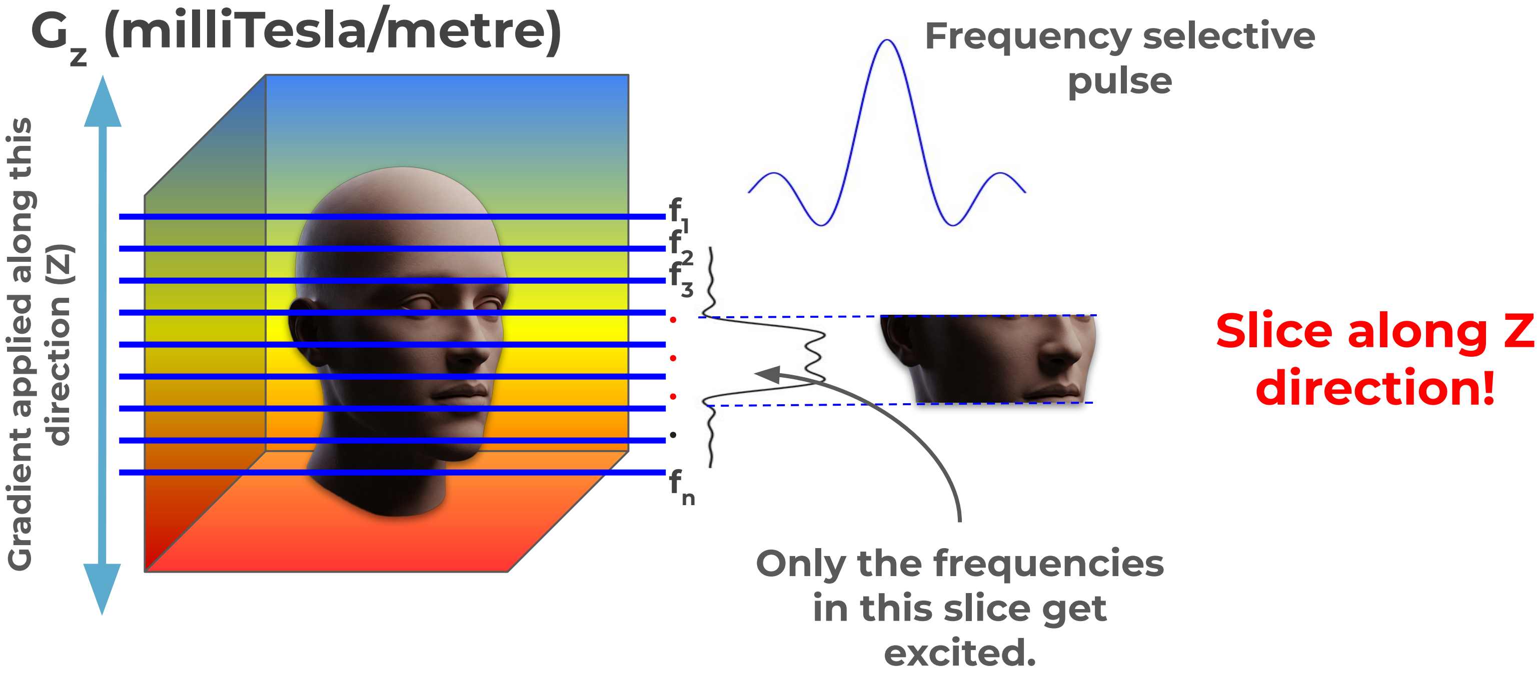
Which means spatial encoding can be done in all directions.

What role does the RF pulse play?

- All RF pulses excite a specific range/band of frequencies
    - **Bandwidth ∝ 1/Pulse duration**
- Shape of this band is dependent on the RF shape

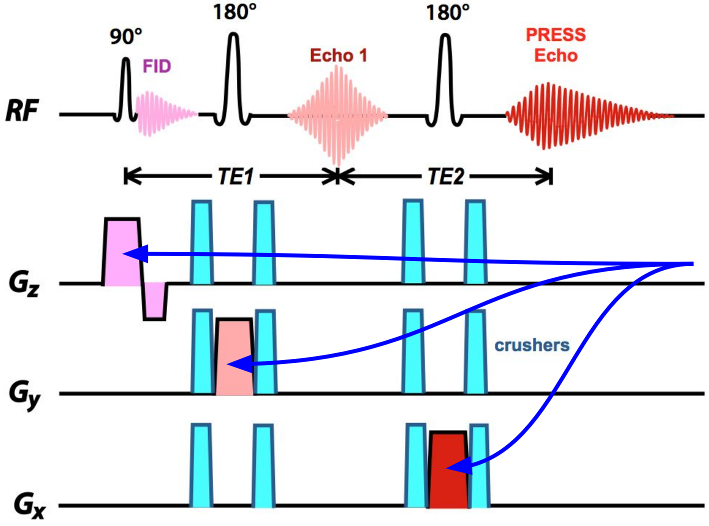


Spatially encoded frequency + Frequency selective pulse = Slice!



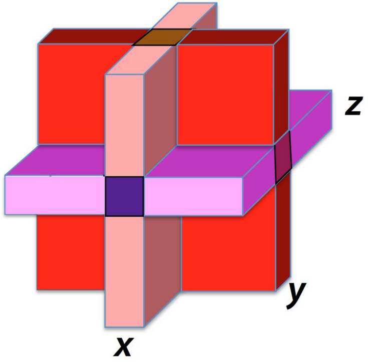
To get a voxel, subsequent slices need to be made along all 3 directions (X, Y and Z)

A simple pulse sequence to achieve voxel selection is PRESS (Point RESolved Spectroscopy)



Slice selection gradients

The **PRESS signal** at the end of the sequence is a **spin-echo** derived only from nuclei that have **experienced all 3 RF-pulses.** These protons are located in a **cuboid-shaped voxel** where the three imaging planes overlap.



https://mriquestions.com/press.html