# Introduction to MRI

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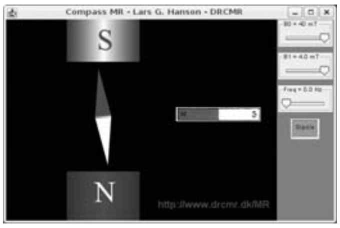
# Java compass




Source: drcmr.dk/JavaCompass
(also on youtube.com with speak)

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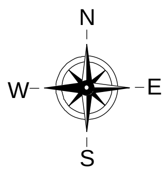
# Imagine 18 compasses on a table. Which way will they point?

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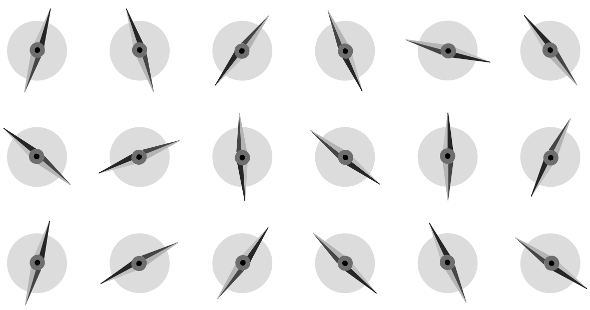
# 18 compasses on a table



... under the influence of many magnetic fields, thus not following that of the earth

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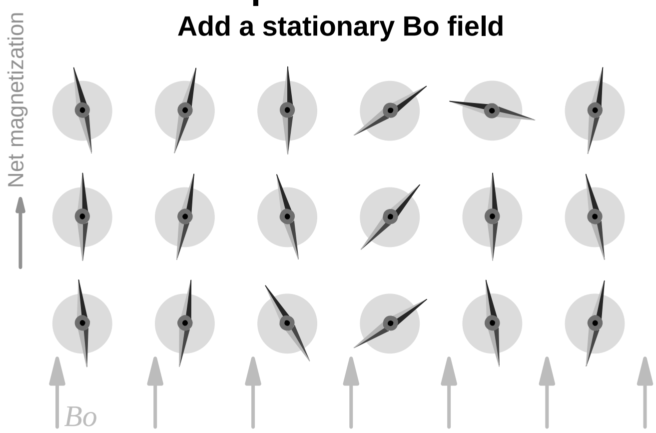
# 18 compasses on a table

**Add a stationary Bo field**

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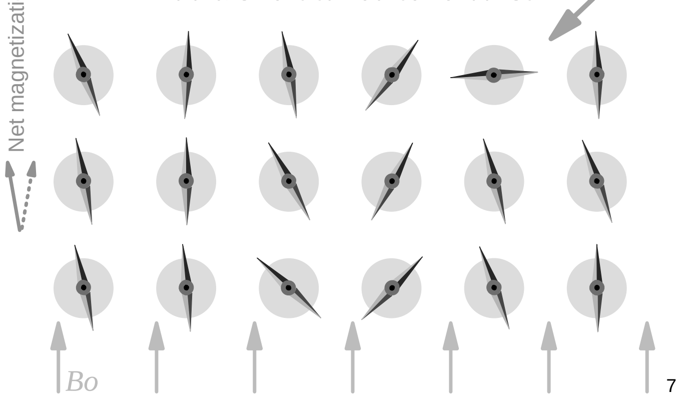
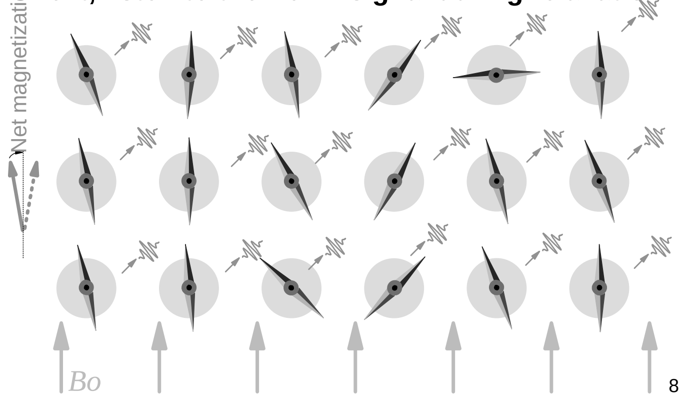
## 18 compasses on a table
### Add a short tuned tone burst




## 18 compasses on a table
### Next, listen to their own signal during relaxation

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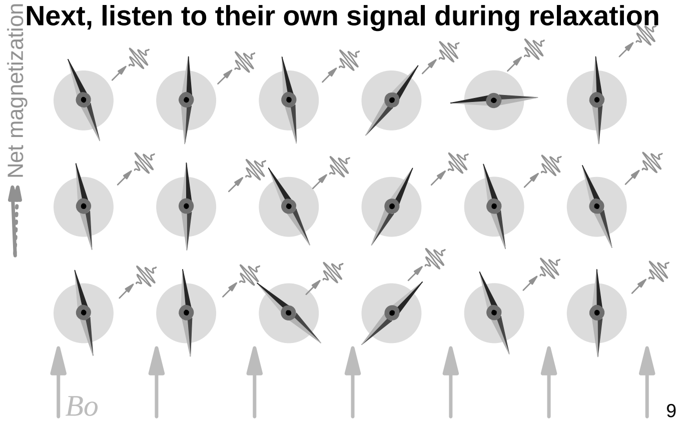
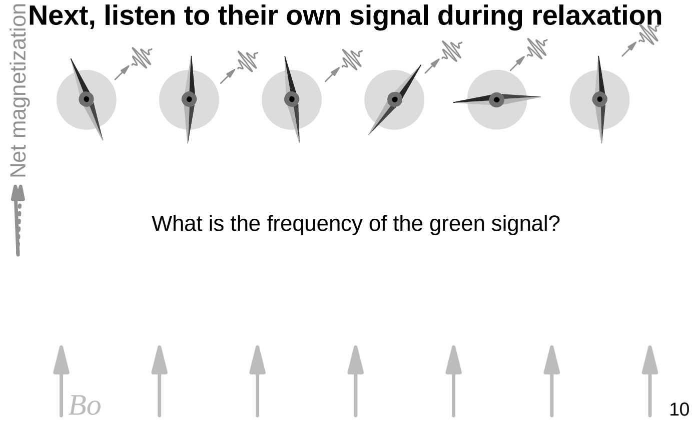
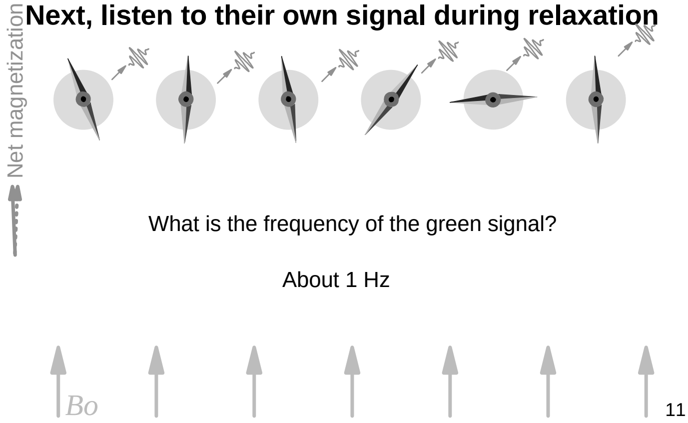


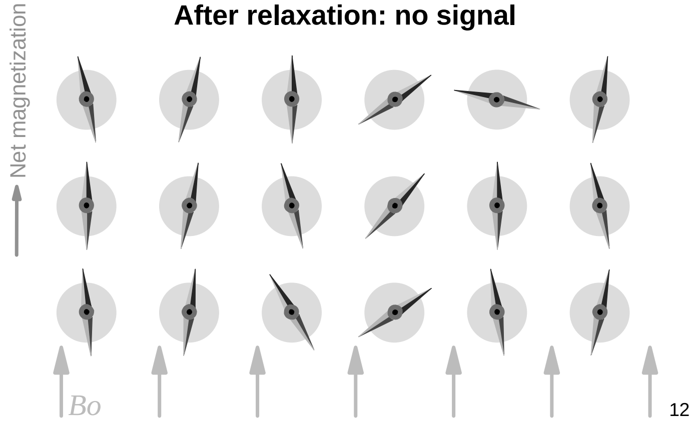

## 18 compasses on a table
### Next, listen to their own signal during relaxation




## 18 compasses on a table
### Next, listen to their own signal during relaxation




## 18 compasses on a table
### After relaxation: no signal



# 18 compasses on a table

## Comparison to MRI

Each compass corresponds to an atomic nucleus, but not all nuclei are magnetic. The most important by far is hydrogen nuclei (protons) primarily found in water in the body.

Only small mobile molecules can be seen with MRI (all other have too short relaxation times to allow detection).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# Vibration versus precession

**Compasses:** When excited, it will vibrate around north in a plane:

**Hydrogen nucleus:** When excited, it will precess in a cone (da: kegle) around north:


The difference is caused by the rotation of the nucleus around their own axis, e.g. gyroscope

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# The spin of the hydrogen nucleus

By transmitting a short tone burst at the Larmor frequency,

$$f_0 = \gamma B_0$$

the spin can be rotated.

$\gamma$ = 42.58 MHz/T for the hydrogen nucleus.

For $B_0$ = 1.5 T, $f_0$ = 63 MHz.

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# The spin of the hydrogen nucleus

The strength of the measured signal:

The more hydrogen atoms (water) the larger the signal

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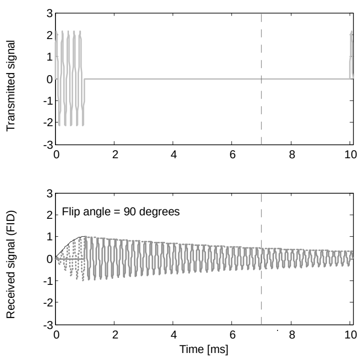
# The transmitted and received signals

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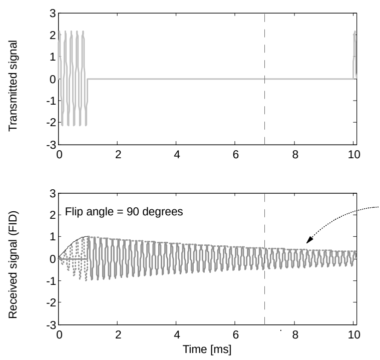
# The transmitted and received signals




The decay rate tells us about the tissue type

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# Imaging

***How to get spatial information?***

The only signal we have available is the *received (decaying) signal*.

How to get spatial information?

- Amplitude
- Decay
- Phase
- Frequency

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# Imaging

***How to get spatial information?***

The only signal we have available is the *received (decaying) signal*.

How to get spatial information?

- Amplitude is proportional to proton density
- Decay is dependent on tissue type
- Phase is irrelevant
- Frequency?

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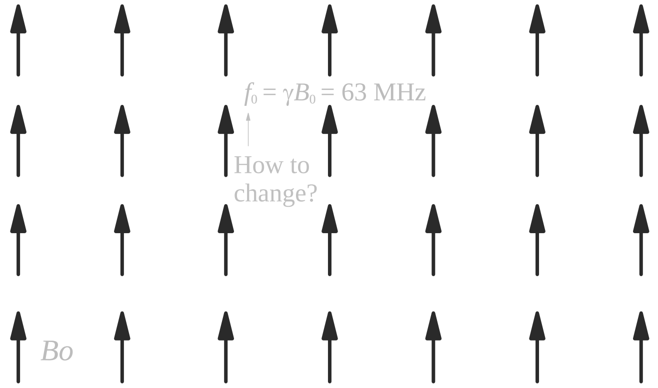
# Imaging

***How to get spatial information?***

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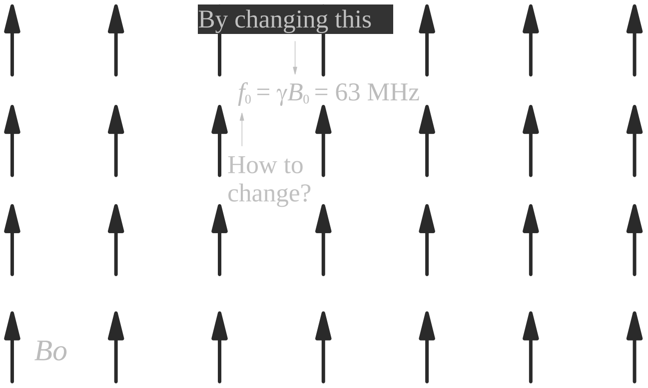
# Imaging

***How to get spatial information?***

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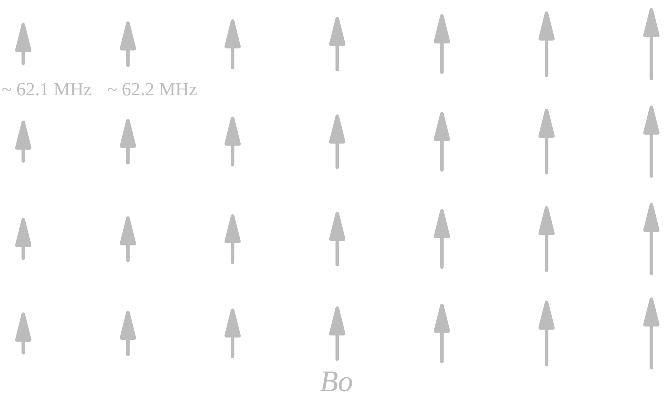
# Imaging

***Gradient coils changes static field and thus Larmor frequency***

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# The MR scanner

***What is needed?***


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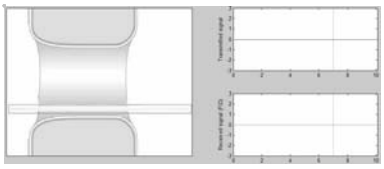
# The MR scanner

***What is needed?***



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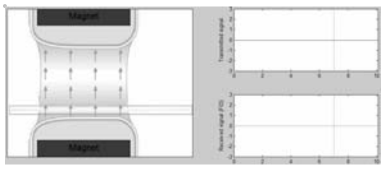
# The MR scanner

***What is needed?***

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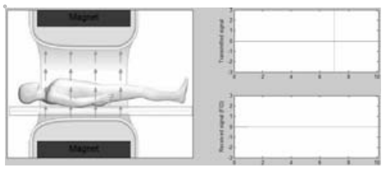
# The MR scanner

***What is needed?***

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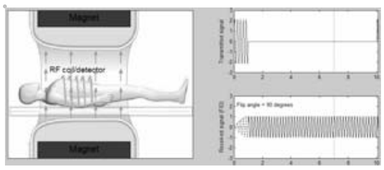
# The MR scanner

***What is needed?***

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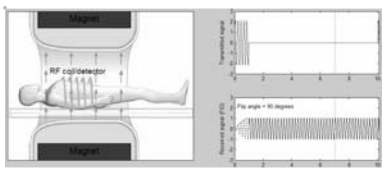
# The MR scanner

***What is needed?***




Do we get an image?

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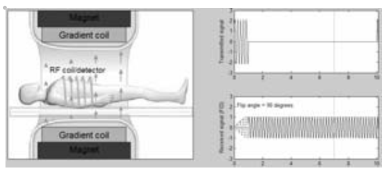
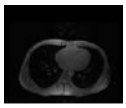
# The MR scanner

***What is needed?***



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# The MR scanner

***What is needed?***

The principal components of an MR scanner:

- Strong (super conducting) magnet for generation of $B_0$ field
- Gradient coils for generating spatial variations in $B_0$ field and thus Larmor frequency
- Coil for emitting radio waves at the Larmor frequency
- Same coil can be used for listening to the radio waves generated by the hydrogen nucleus

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