

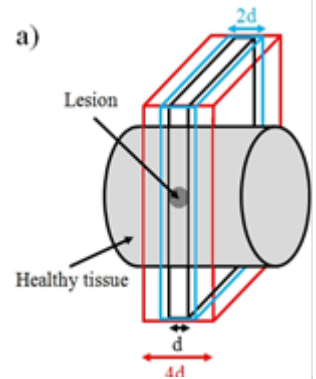
### Problem 1 – SNR vs. Contrast

Three slices of an organ with a lesion are acquired with an imaging device. The position and field of view of each slice are similar. The thickness of the first slice is  $d$ , whereas  $2d$  and  $4d$  are chosen for the second and third ones (a). The pixel values recorded for each acquisition are presented in (b), (c) and (d).

Remarks: (i) One can assume the noise per pixel as constant throughout the images. (ii) The signal increases linearly with the slice thickness.

Which acquisition provides the highest:

- 1) SNR?
- 2) Contrast between lesion and healthy tissue ( $\text{Contrast}_{A-B} = \frac{S_A - S_B}{S_A + S_B}$ )?
- 3) CNR between lesion and healthy tissue?



|                 |   |    |   |   |                  |    |    |    |   |                  |    |    |    |   |
|-----------------|---|----|---|---|------------------|----|----|----|---|------------------|----|----|----|---|
| b)              |   |    |   |   | c)               |    |    |    |   | d)               |    |    |    |   |
| 1               | 1 | 1  | 1 | 1 | 1                | 1  | 1  | 1  | 1 | 1                | 1  | 1  | 1  | 1 |
| 1               | 5 | 5  | 5 | 1 | 1                | 10 | 10 | 10 | 1 | 1                | 20 | 20 | 20 | 1 |
| 1               | 5 | 10 | 5 | 1 | 1                | 10 | 15 | 10 | 1 | 1                | 20 | 25 | 20 | 1 |
| 1               | 5 | 5  | 5 | 1 | 1                | 10 | 10 | 10 | 1 | 1                | 20 | 20 | 20 | 1 |
| 1               | 1 | 1  | 1 | 1 | 1                | 1  | 1  | 1  | 1 | 1                | 1  | 1  | 1  | 1 |
| Thickness = $d$ |   |    |   |   | Thickness = $2d$ |    |    |    |   | Thickness = $4d$ |    |    |    |   |

### Problem 2 – Voxel Size vs. SNR

In imaging and spectroscopic experiments, signals from 3-dimensional parts ('voxels', i.e. 3D pixels) of the object of interest are localised, i.e. can be differentiated in space. The size of a voxel (usually given in cubic mm) defines thus the spatial resolution of the experiment. Let's now assume that the signal strength in a single (isotropic, i.e. all edges have the same length) voxel is proportional to the number of molecules in it. A high spatial resolution is preferable, so one wants to reduce the voxel size.

- a) How does the signal change if the edges of the voxel are reduced by 20%/50%/80%?
- b) What could be a possible solution to keep the original SNR (and the price to pay)?

### Problem 3 – Optimising CNR

In magnetic resonance imaging (MRI), one important time constant characterising biological tissues is the so-called  $T_1$  time. After excitation (how this exactly works will be explained later in the course), the tissue signal recovers according to  $s_{\text{tissue}}(t) = 1 - e^{-t/T_1}$

In biomedical imaging, it is often crucial to be able to differentiate between different tissues. In a human brain imaging experiment, we want to observe two different brain tissues: gray matter ( $T_{1,\text{GM}} = 1300$  ms) and white matter ( $T_{1,\text{WM}} = 800$  ms).

- a) Express in words what the CNR (Contrast to Noise Ratio) is and give its formula. What is the difference with SNR?
- b) Calculate the time  $t_{\text{max}}$  after the excitation when one should measure the signals from gray and white matter to obtain the best CNR between the two (assume noise to be constant).
- c) Discuss how the SNR influences this experiment. Is it preferable to have maximal CNR or SNR in the given experimental setup?