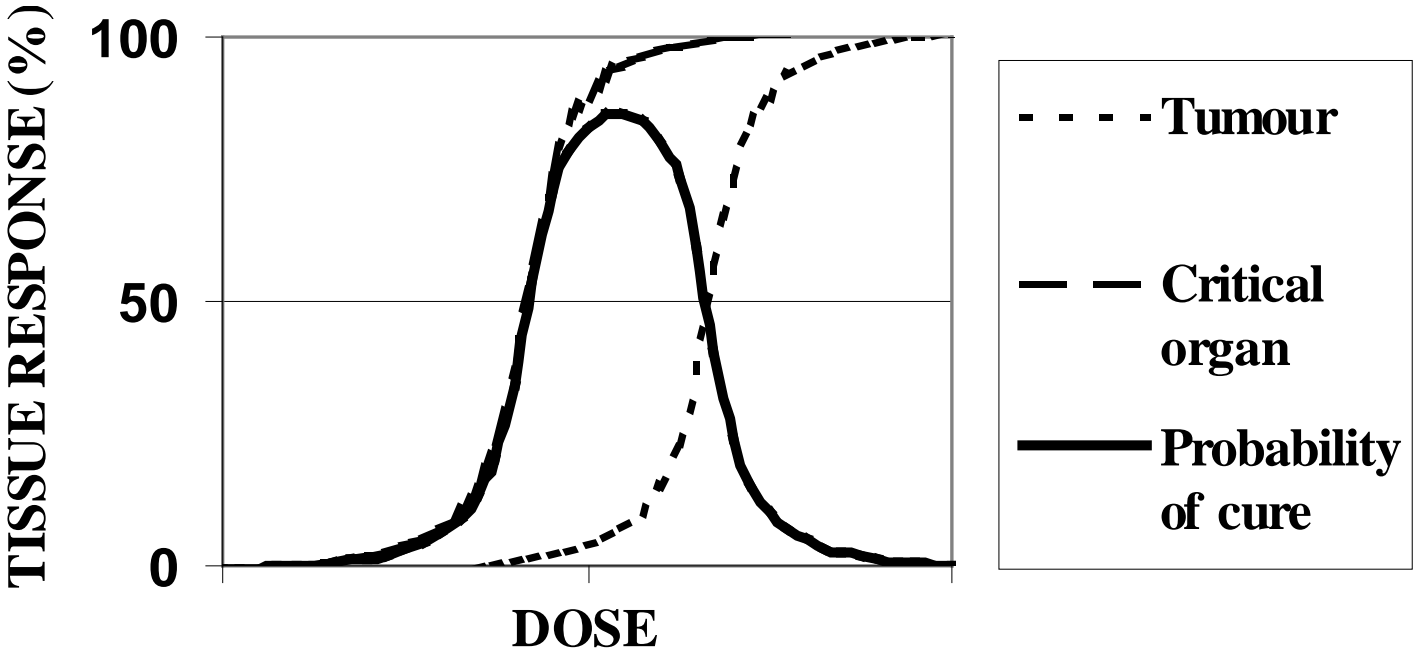


# Internal dosimetry

Dosimetry in radionuclide therapy and  
nuclear medical diagnostics  
are two different things!  
Do not mix them up

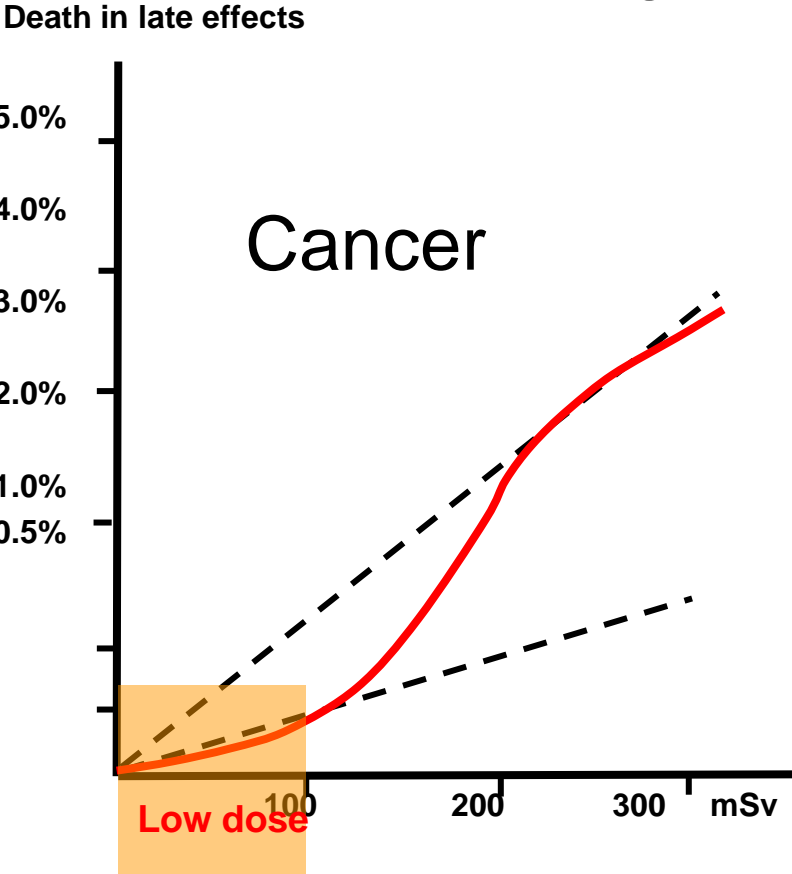
# RADIOTHERAPY



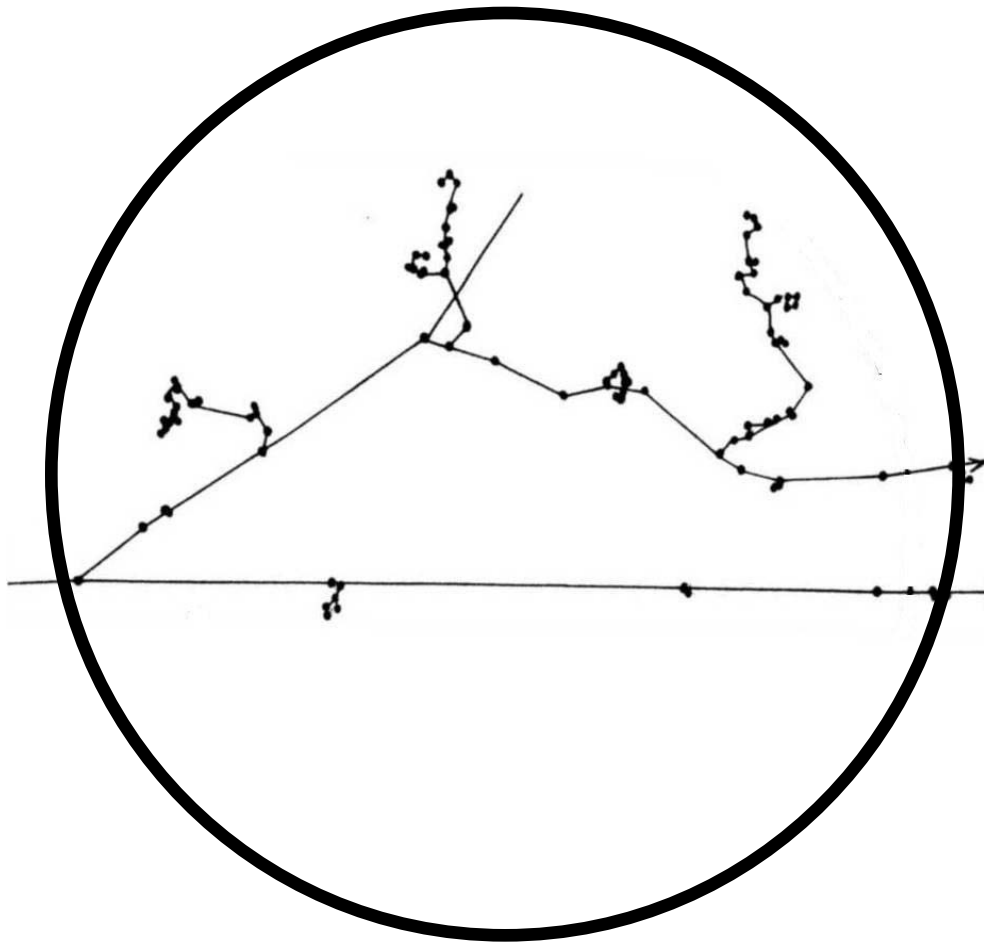
10-100 Gy

# Diagnostics

*ICRP linear model*



# The electrons are delivering dose



$$D = \frac{\text{Energy}}{\text{Mass}} \left[ \frac{\text{J}}{\text{kg}} \right] \text{ [Gy]}$$

$$S = 0.6 \text{ keV} / \mu\text{m}$$

$$\text{Range} = 10 \mu\text{m}$$

$$D = \frac{6 \cdot 10^3 [\text{eV}] \cdot 1.6 \cdot 10^{-19} [\text{J} / \text{eV}]}{10^{-12} [\text{kg}]}$$

$$D \approx 10^{-3} \text{ Gy}$$

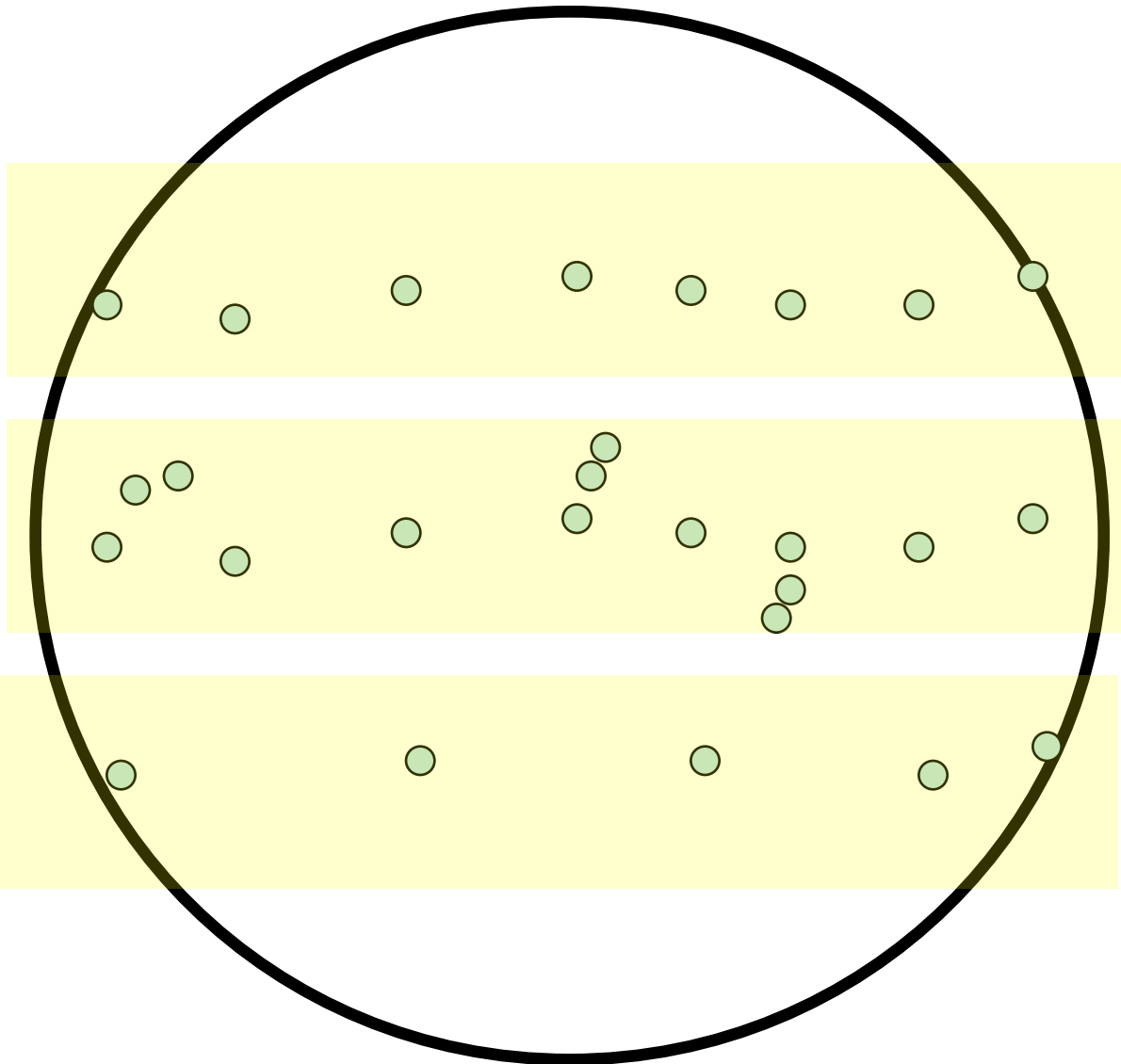
# The electrons are delivering dose

## Microdosimetry

D= 0.5 mGy

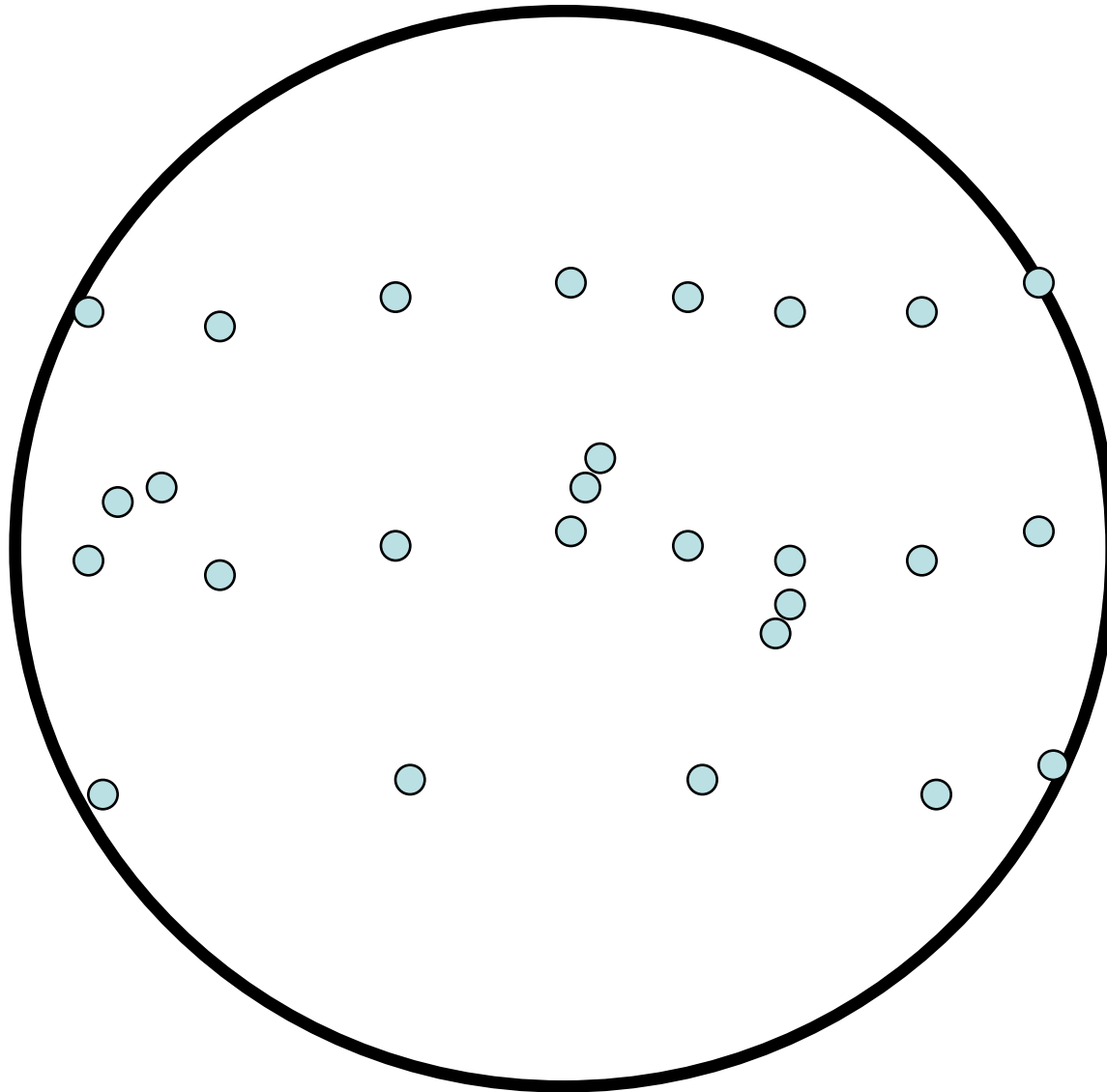
D= 1 mGy

D= 0.2 mGy



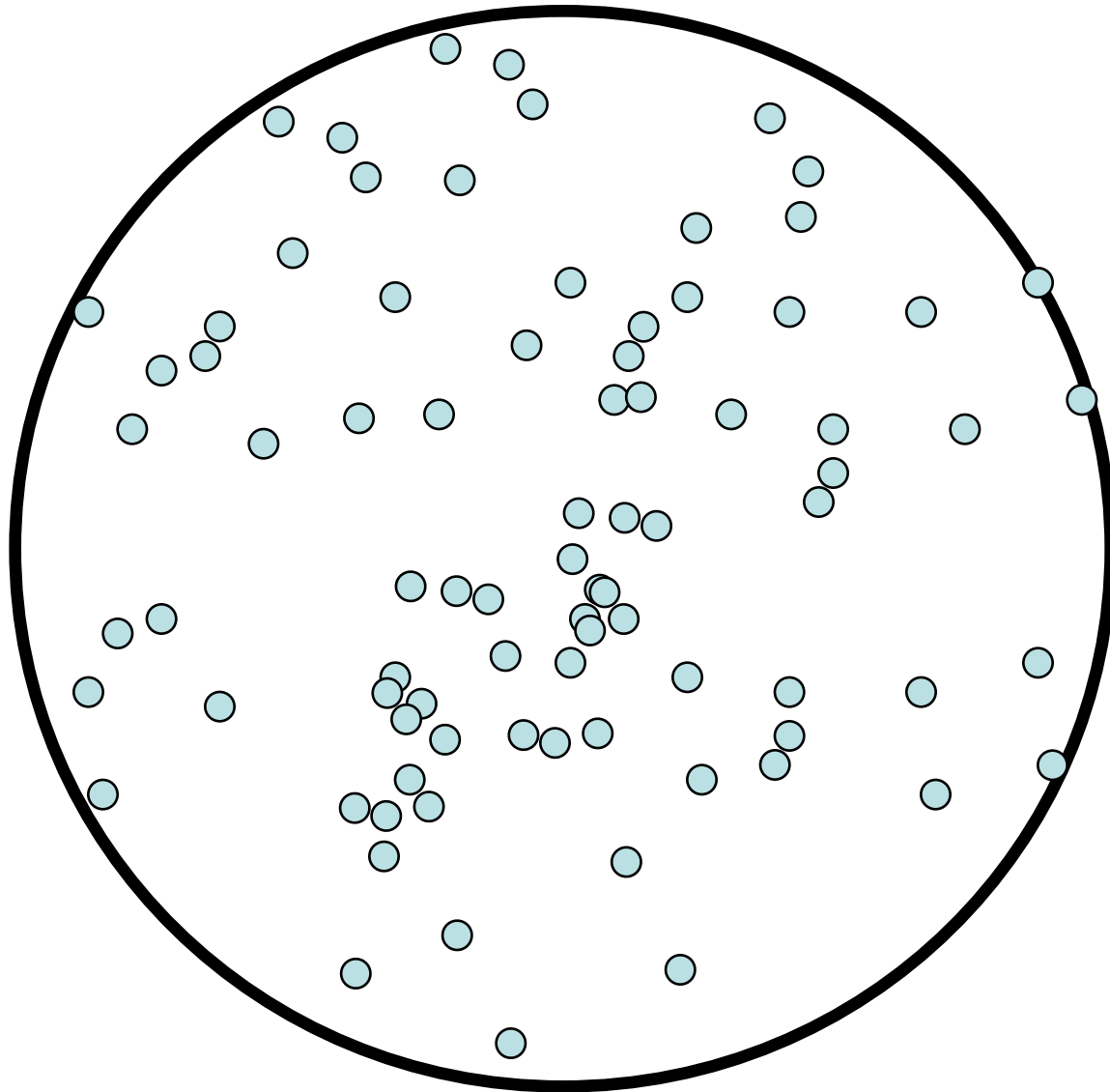
# The electrons are delivering dose

Microdosimetry



D= 1 mGy

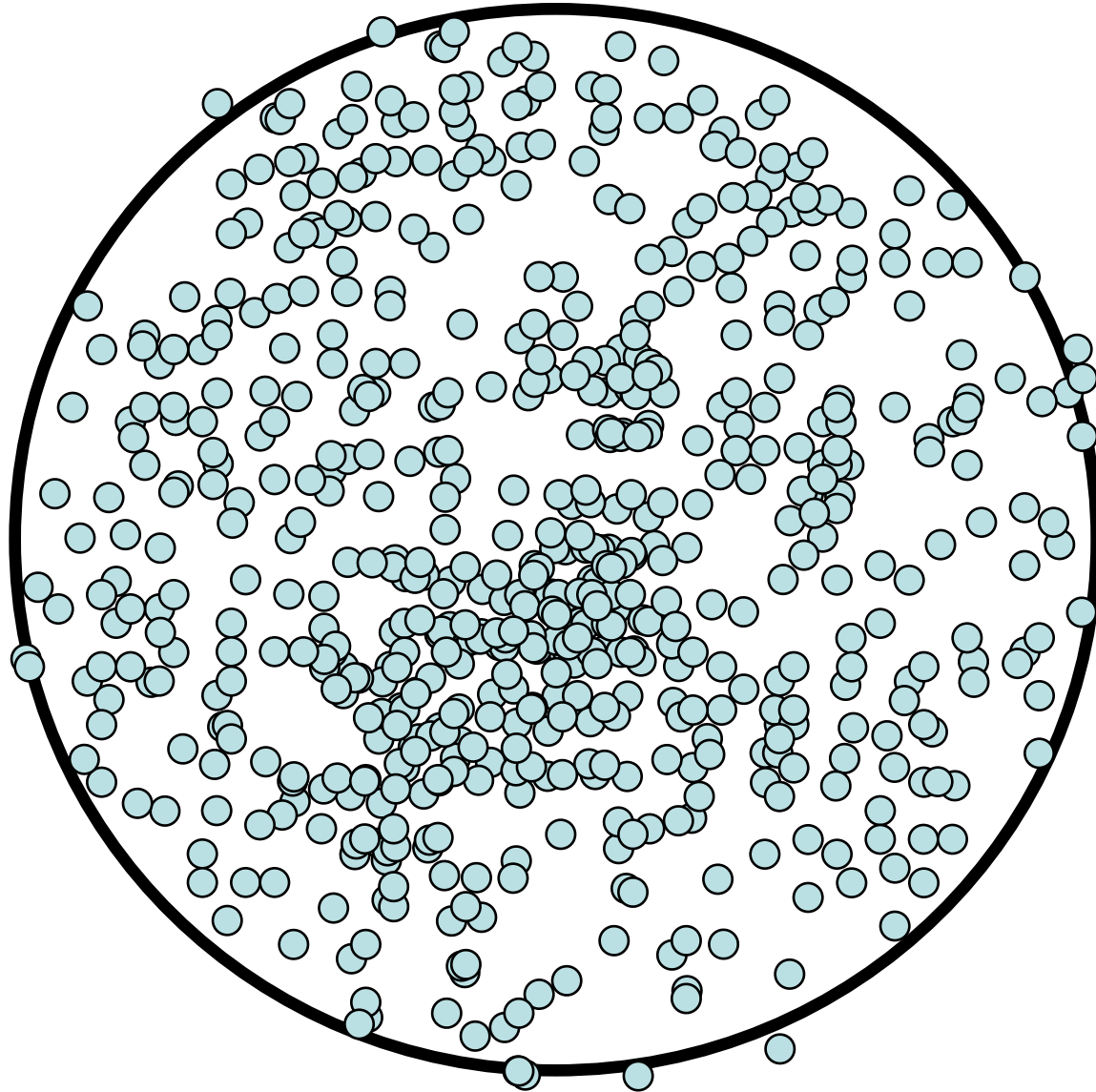
# The electrons are delivering dose



Microdosimetry

D= 10 mGy

# The electrons are delivering dose



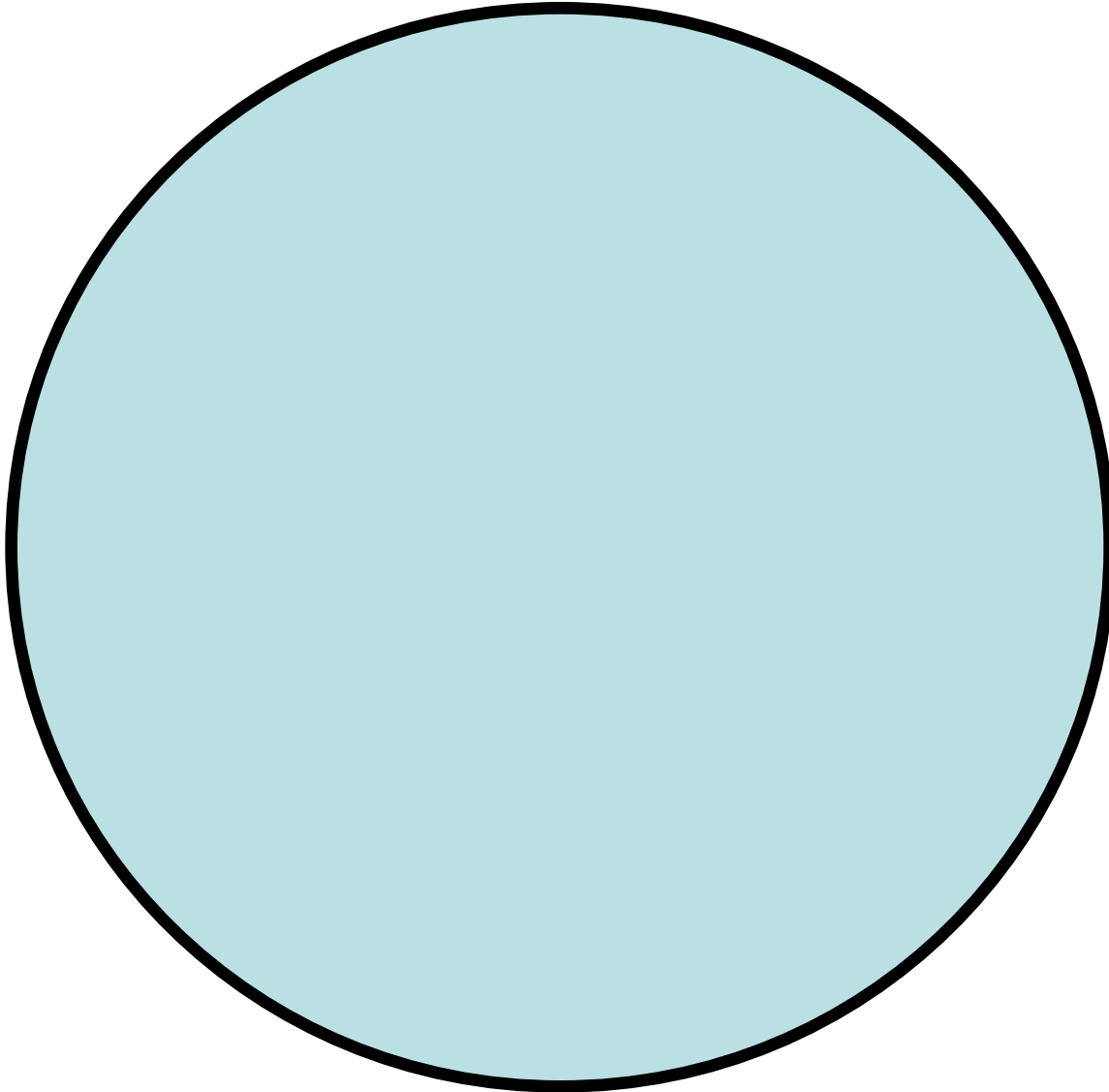
Microdosimetry

D= 100 mGy

# The electrons are delivering dose

Mean absorbed dose

$D > 1 \text{ Gy}$



# Absorbed dose calculations

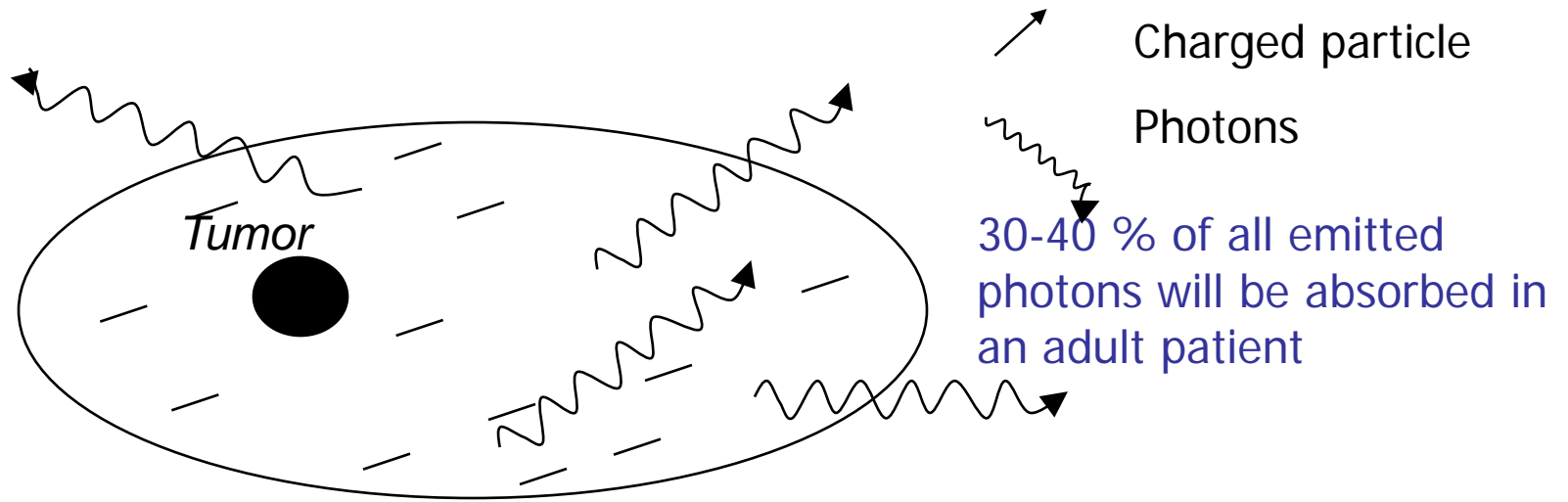
## Different radionuclides







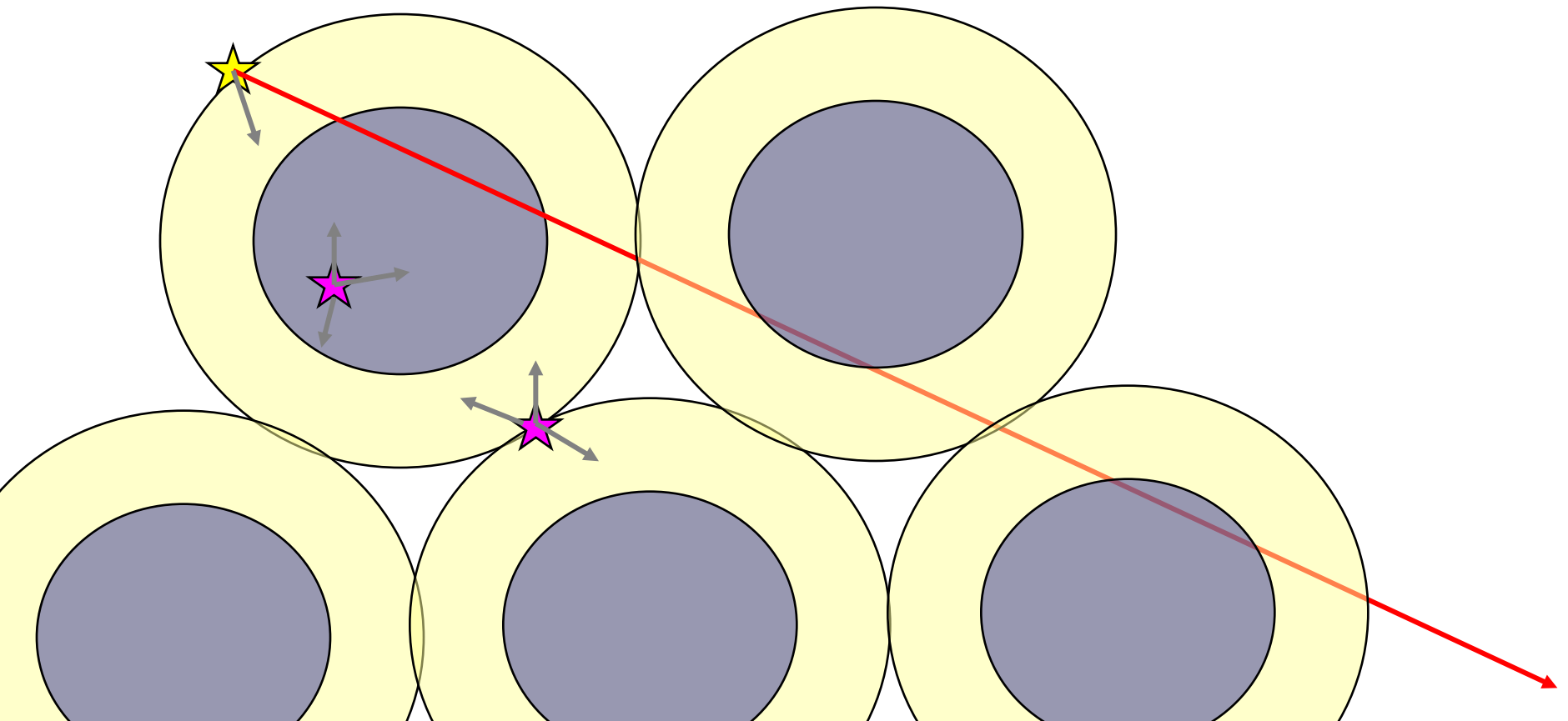
# What about photons?



# Dosimetric characterization of radionuclides

## Subcellular activity distribution

- Important for electron energies  $<40$  keV
- Important for Auger-electron emitters



# Internal dosimetry

Mean absorbed dose

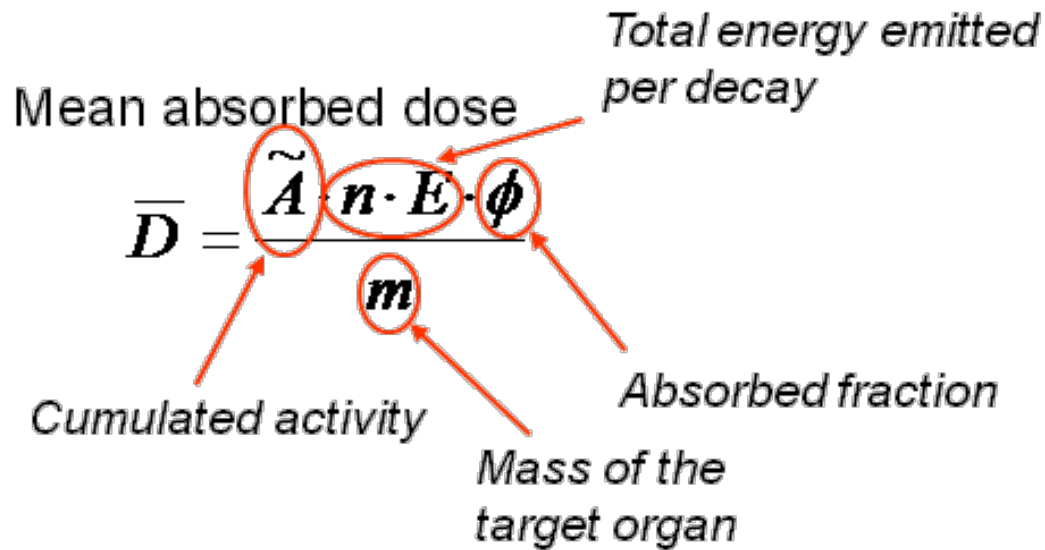
$$\bar{D} = \frac{\tilde{A} \cdot n \cdot E \cdot \phi}{m}$$

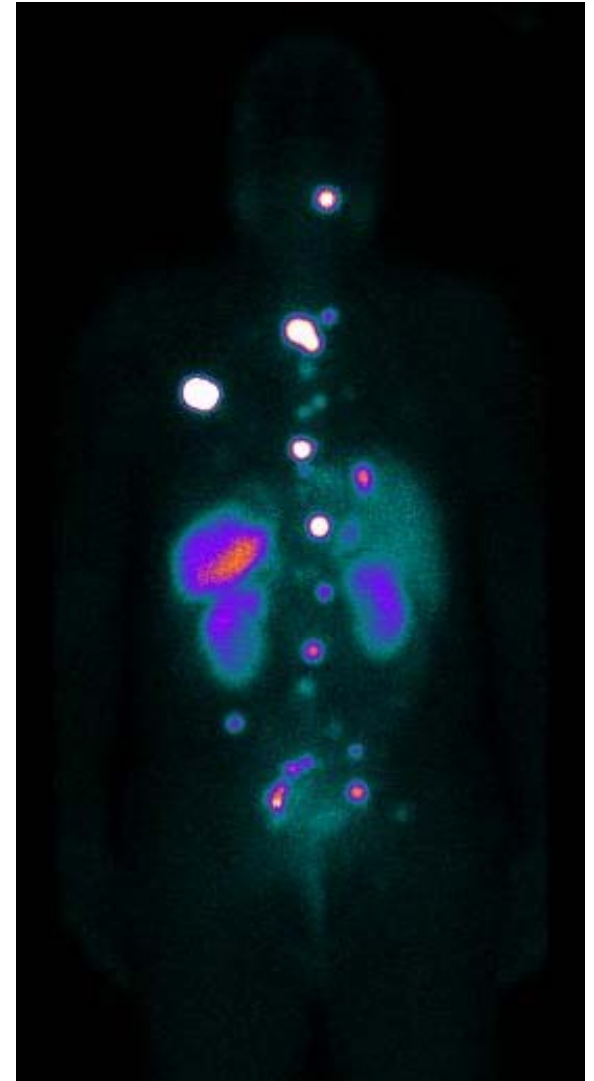
Cumulated activity

Mass of the target organ

Absorbed fraction

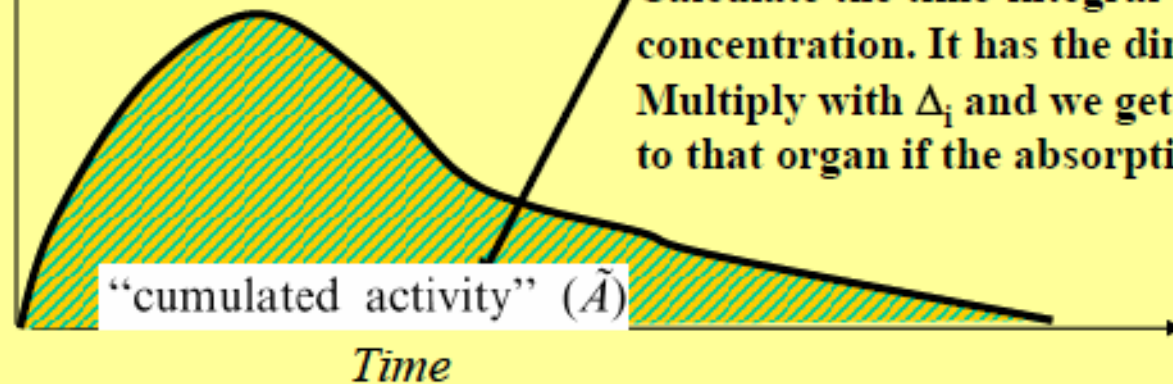
Total energy emitted per decay

The diagram shows the equation for mean absorbed dose,  $\bar{D} = \frac{\tilde{A} \cdot n \cdot E \cdot \phi}{m}$ . Red circles highlight the variables  $\tilde{A}$ ,  $n \cdot E$ ,  $\phi$ , and  $m$ . Red arrows point from text labels to these variables: 'Cumulated activity' to  $\tilde{A}$ , 'Mass of the target organ' to  $m$ , 'Absorbed fraction' to  $\phi$ , and 'Total energy emitted per decay' to  $n \cdot E$ . The text 'Mean absorbed dose' is positioned above the equation.



Radio-  
activity  
concentration

We measure the radioactivity concentration  
in an organ as a function of time.



Calculate the time-integral of the radioactivity concentration. It has the dimensions Bq/kg \* h. Multiply with  $\Delta_i$  and we get the absorbed dose to that organ if the absorption is 100 %



$$\phi = \frac{\text{Absorbed energy fraction}}{\text{Total emitted energy}}$$

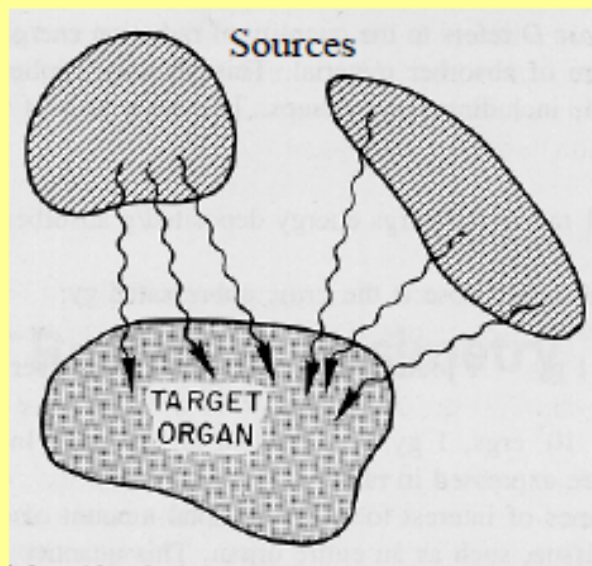
$$D = \frac{k \tilde{A} \sum_i n_i E_i \phi_i}{m}$$



$$D = \tilde{A}S$$

$$S = \frac{k \sum_i n_i E_i \phi_i}{m}$$

# MIRD Medical Internal Radiation Dose



The dose to an organ is composed by the self-absorbed dose and by the cross-talk of dose between the organs.

$$D_{r_k} = \sum_h \tilde{A}_h S(r_k \leftarrow r_h)$$

source region ( $r_h$ )

target region ( $r_k$ )

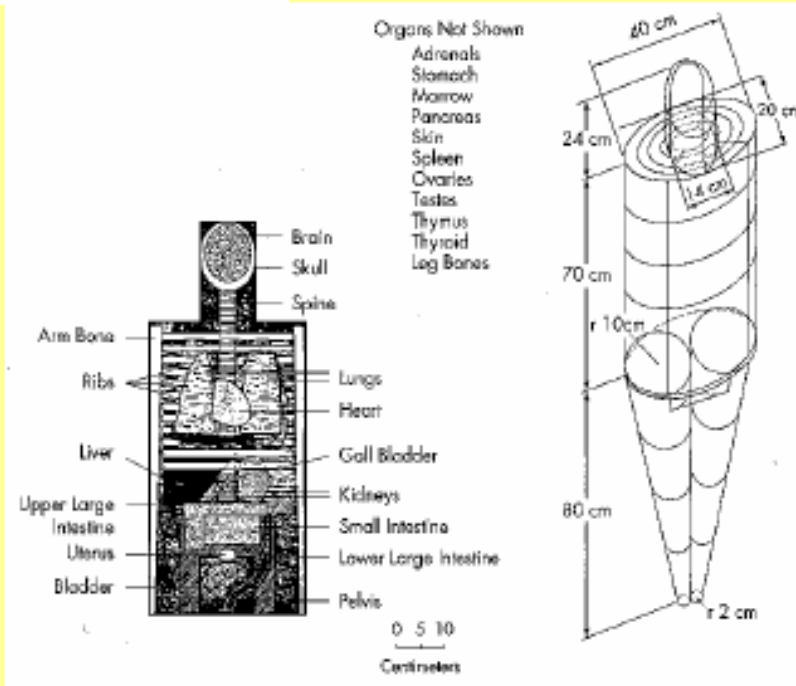


$$\tau_h = \frac{\tilde{A}_h}{A_0}$$

If the area under the time-activity curve for a source organ (cumulated activity) is normalized to the amount of activity administered ( $A_0$ ), this is defined as "residence time" (Loevinger *et al.*, 1988).

$$D_{rk} = A_0 \sum_h \tau_h S(r_k \leftarrow r_h)$$

The calculations tends to be tedious. Use the computer!



Nuclide	ALI	Nuclide	ALI	Nuclide	ALI
<sup>3</sup> H	3*10 <sup>9</sup>	<sup>65</sup> Zn	1*10 <sup>7</sup>	<sup>129</sup> I	2*10 <sup>5</sup>
<sup>14</sup> C	9*10 <sup>7</sup>	<sup>69m</sup> Zn	2*10 <sup>8</sup>	<sup>130</sup> I	1*10 <sup>7</sup>
<sup>18</sup> F	2*10 <sup>9</sup>	<sup>67</sup> Ga	3*10 <sup>8</sup>	<sup>131</sup> I	1*10 <sup>6</sup>
<sup>22</sup> Na	2*10 <sup>7</sup>	<sup>68</sup> Ga	6*10 <sup>8</sup>	<sup>132</sup> I	1*10 <sup>8</sup>
<sup>24</sup> Na	1*10 <sup>8</sup>	<sup>73</sup> As	6*10 <sup>7</sup>	<sup>129</sup> Cs	9*10 <sup>6</sup>
<sup>32</sup> P	1*10 <sup>7</sup>	<sup>74</sup> As	3*10 <sup>7</sup>	<sup>130</sup> Cs	2*10 <sup>9</sup>
<sup>33</sup> P	1*10 <sup>8</sup>	<sup>75</sup> Se	2*10 <sup>7</sup>	<sup>131</sup> Cs	8*10 <sup>8</sup>
<sup>35</sup> S	8*10 <sup>7</sup>	<sup>76</sup> Br	1*10 <sup>8</sup>	<sup>134</sup> Cs	3*10 <sup>6</sup>
<sup>36</sup> Cl	9*10 <sup>6</sup>	<sup>77</sup> Br	6*10 <sup>8</sup>	<sup>134m</sup> Cs	4*10 <sup>9</sup>
<sup>38</sup> Cl	6*10 <sup>8</sup>	<sup>82</sup> Br	1*10 <sup>8</sup>	<sup>137</sup> Cs	4*10 <sup>6</sup>
<sup>42</sup> K	2*10 <sup>8</sup>	<sup>81m</sup> Rb	9*10 <sup>9</sup>	<sup>131</sup> Ba	1*10 <sup>8</sup>
<sup>43</sup> K	2*10 <sup>8</sup>	<sup>81</sup> Rb	1*10 <sup>9</sup>	<sup>133m</sup> Ba	9*10 <sup>7</sup>
<sup>45</sup> Ca	3*10 <sup>7</sup>	<sup>86</sup> Rb	2*10 <sup>7</sup>	<sup>135m</sup> Ba	1*10 <sup>8</sup>
<sup>47</sup> Ca	3*10 <sup>7</sup>	<sup>88</sup> Rb	7*10 <sup>8</sup>	<sup>140</sup> La	2*10 <sup>7</sup>
<sup>51</sup> Cr	7*10 <sup>8</sup>	<sup>89</sup> Rb	1*10 <sup>9</sup>	<sup>169</sup> Yb	3*10 <sup>7</sup>
<sup>52</sup> Mn	3*10 <sup>7</sup>	<sup>85m</sup> Sr	8*10 <sup>9</sup>	<sup>192</sup> Ir	8*10 <sup>6</sup>
<sup>52m</sup> Mn	1*10 <sup>9</sup>	<sup>85</sup> Sr	6*10 <sup>7</sup>	<sup>198</sup> Au	4*10 <sup>7</sup>
<sup>54</sup> Mn	3*10 <sup>7</sup>	<sup>87m</sup> Sr	1*10 <sup>9</sup>	<sup>197</sup> Hg	2*10 <sup>8</sup>
<sup>56</sup> Mn	2*10 <sup>8</sup>	<sup>89</sup> Sr	5*10 <sup>6</sup>	<sup>203</sup> Hg	2*10 <sup>7</sup>
<sup>52</sup> Fe	3*10 <sup>7</sup>	<sup>90</sup> Sr	1*10 <sup>5</sup>	<sup>201</sup> Tl	6*10 <sup>8</sup>
<sup>55</sup> Fe	7*10 <sup>7</sup>	<sup>90</sup> Y	2*10 <sup>7</sup>	<sup>204</sup> Tl	6*10 <sup>7</sup>
<sup>59</sup> Fe	1*10 <sup>7</sup>	<sup>99</sup> Mo	4*10 <sup>7</sup>	<sup>210</sup> Pb	9*10 <sup>3</sup>
<sup>56</sup> Co	7*10 <sup>6</sup>	<sup>99m</sup> Tc	3*10 <sup>9</sup>	<sup>212</sup> Pb	1*10 <sup>6</sup>
<sup>57</sup> Co	2*10 <sup>7</sup>	<sup>109</sup> Cd	1*10 <sup>6</sup>	<sup>210</sup> Po	2*10 <sup>4</sup>
<sup>58</sup> Co	3*10 <sup>7</sup>	<sup>115</sup> Cd	3*10 <sup>7</sup>	<sup>226</sup> Ra	2*10 <sup>4</sup>
<sup>60</sup> Co	1*10 <sup>6</sup>	<sup>111</sup> In	2*10 <sup>8</sup>	<sup>232</sup> Th	4*10 <sup>1</sup>
<sup>63</sup> Ni	6*10 <sup>7</sup>	<sup>113m</sup> In	2*10 <sup>9</sup>	<sup>238</sup> U	2*10 <sup>3</sup>
<sup>64</sup> Cu	4*10 <sup>8</sup>	<sup>124</sup> Sb	9*10 <sup>6</sup>	<sup>241</sup> Am	2*10 <sup>2</sup>
<sup>67</sup> Cu	2*10 <sup>8</sup>	<sup>123</sup> I	1*10 <sup>8</sup>	<sup>244</sup> Cm	4*10 <sup>2</sup>
<sup>62</sup> Zn	5*10 <sup>7</sup>	<sup>125</sup> I	1*10 <sup>6</sup>	<sup>252</sup> Cf	1*10 <sup>3</sup>

# Annual Limits of Intake