RADIATION HAZARDS

An Introduction

by

Jess H. Brewer

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"No matter how much money you have, how good your health care provider or how healthy your diet and life style, ***you***, ***personally***, *are going to* ***die***."

This may no longer be certain for some of our children, but it still makes an excellent *starting point* for any discussion of ***hazards***.

We cannot (for now) avoid dying, but we can exercise *some* influence over *when* we will die and *from what causes*.

We also (for now) get to choose how much of our enjoyment of life and liberty we sacrifice to this effort.

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What *does* the Damage?

- *Enough intensity* of ***anything*** will "***cook***" you.
- *Highly reactive* ***free radicals*** produced by ***Ionizing Radiation***.

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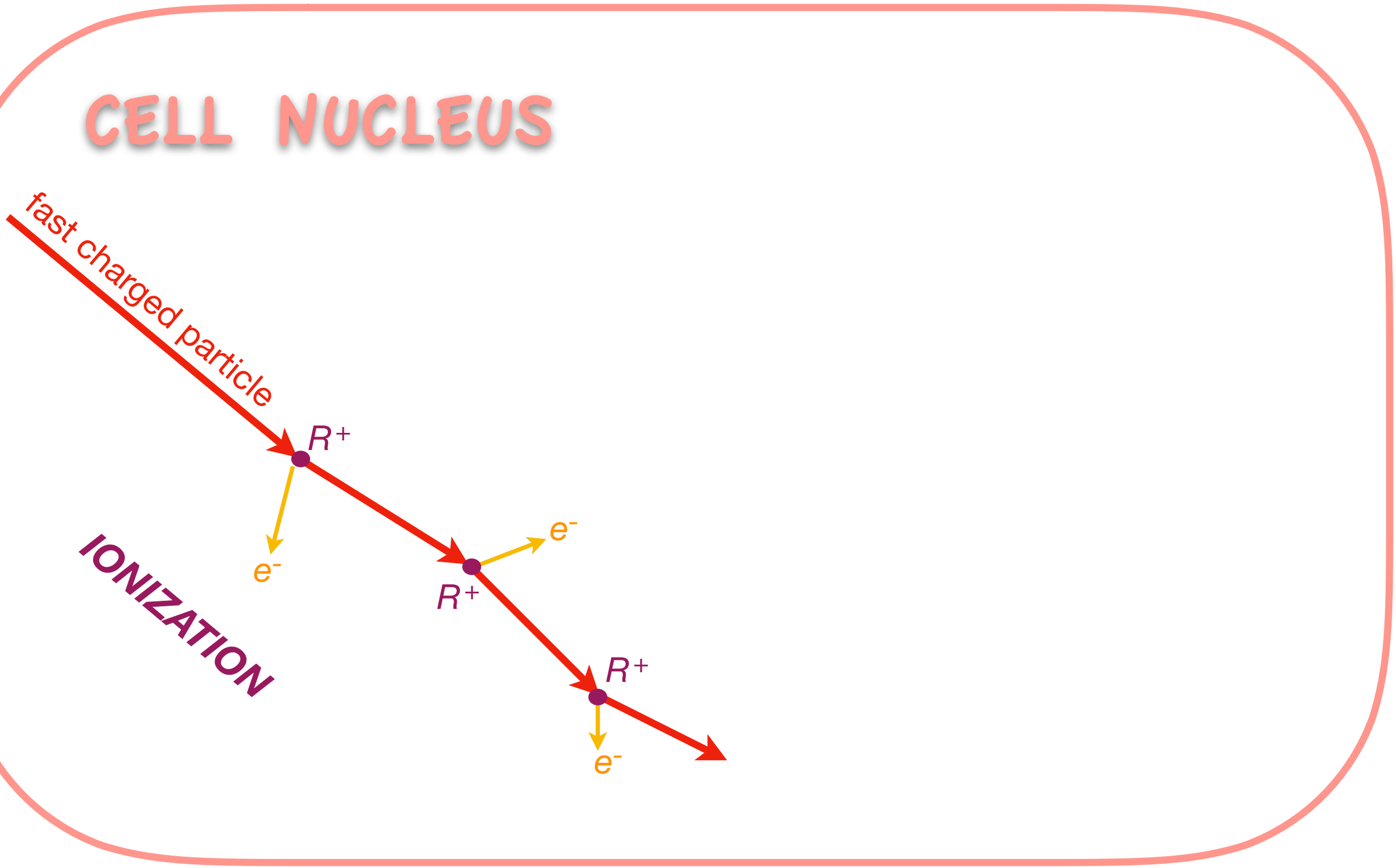

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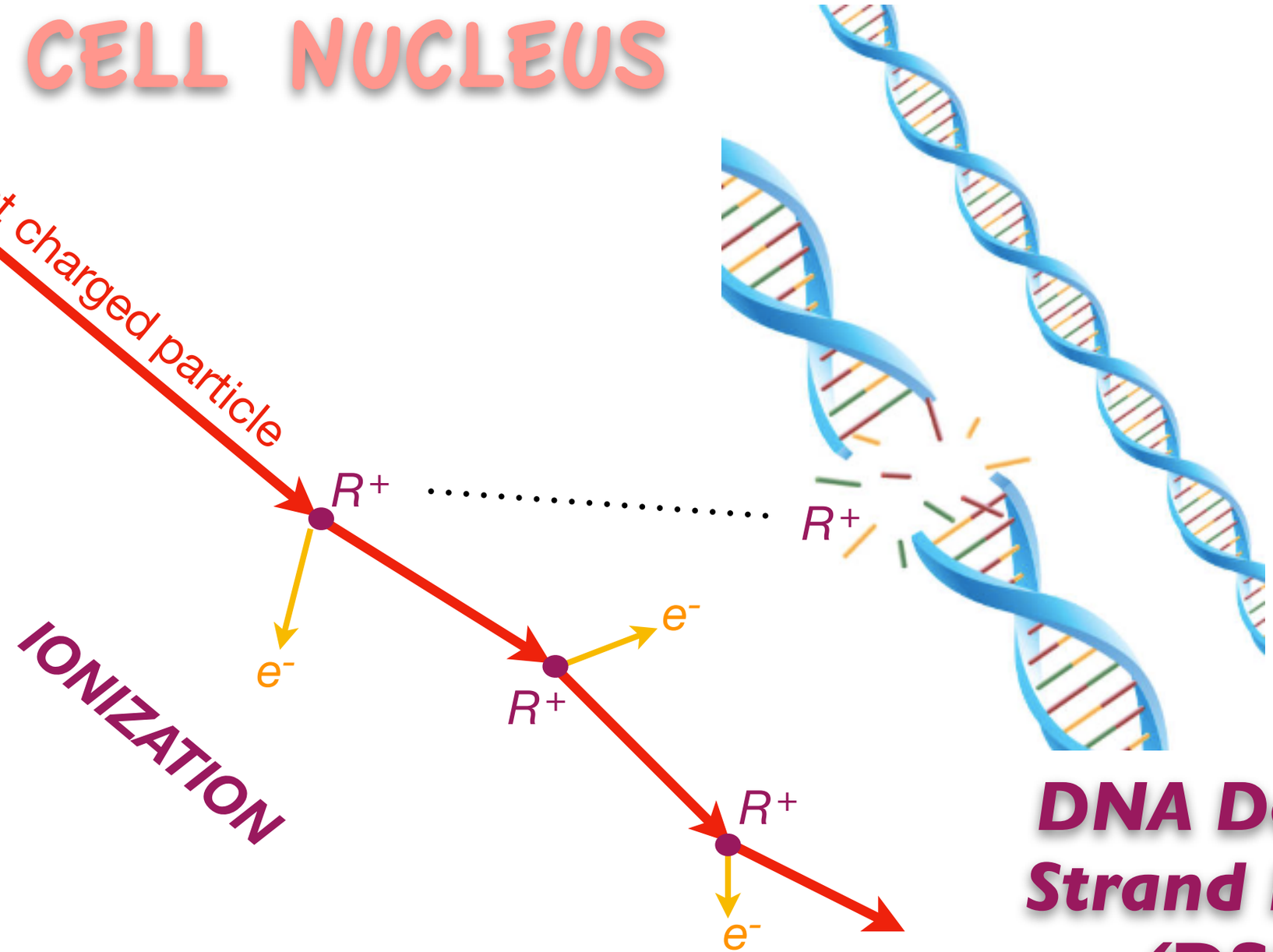

DNA Double Strand Break (DSB)

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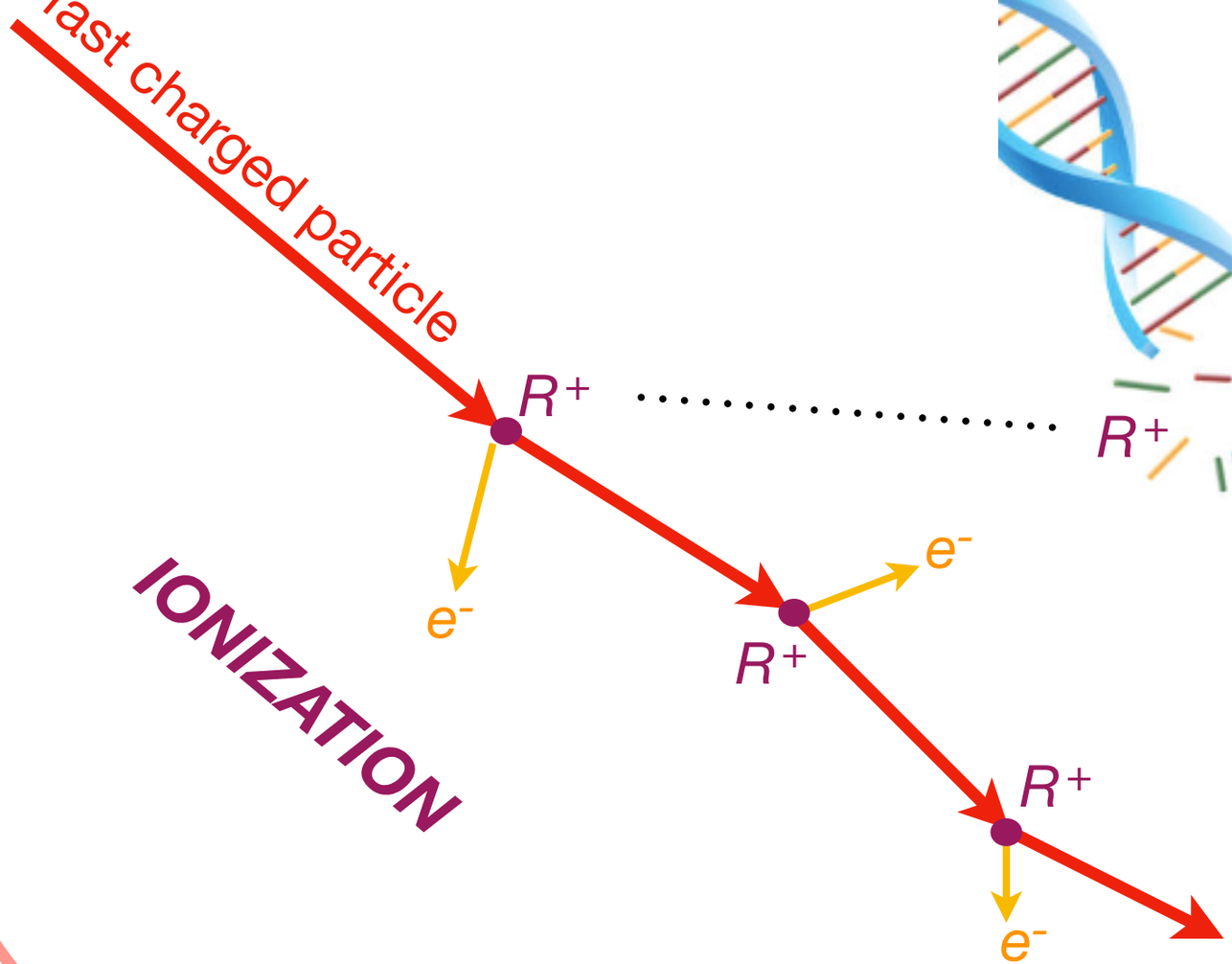

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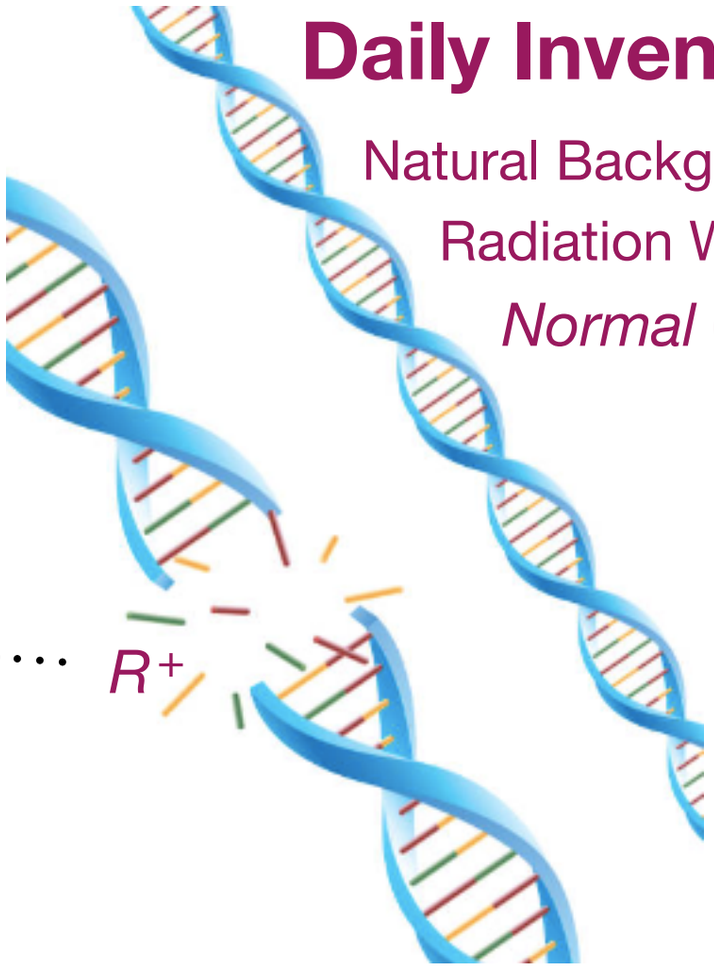

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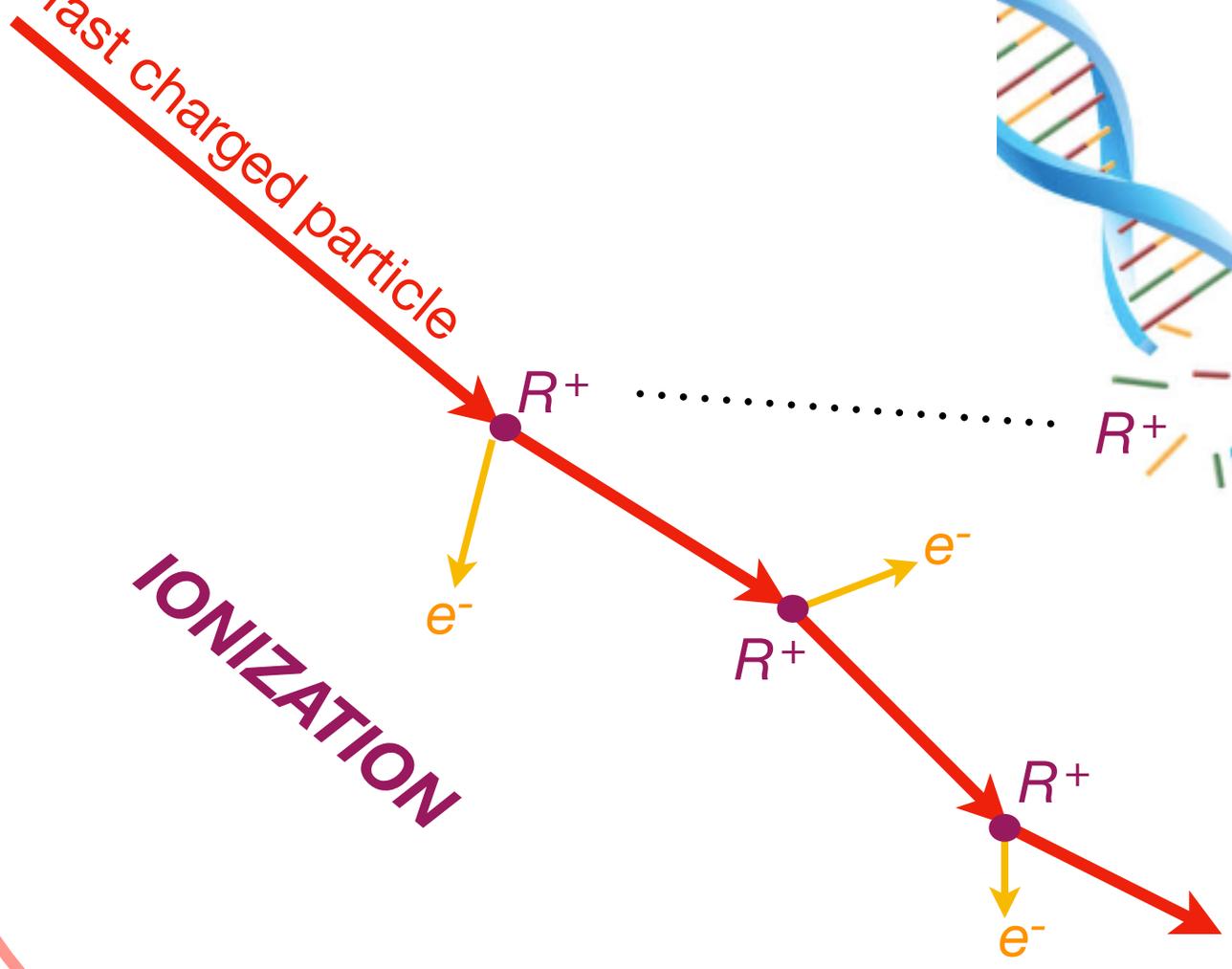

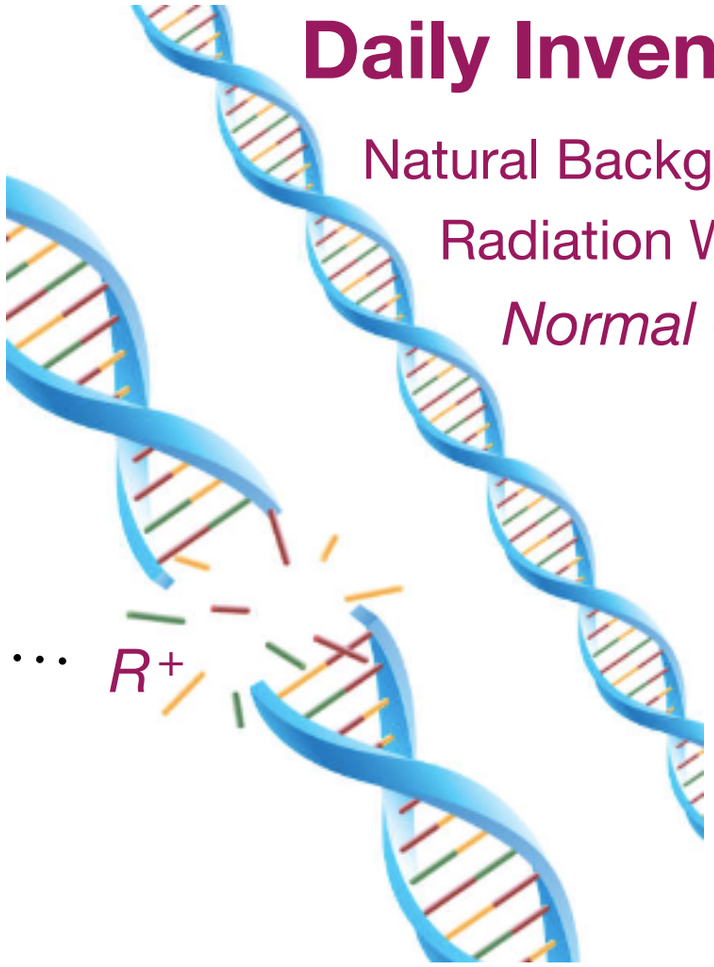

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Usual **healing** time: ***hours*** to ***days***

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- **Cancer** [most unpleasant]

Runaway replicative zeal of a misguided cell…

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Dose may be more than 10,000 times maximum legal limit for “accidental” radiation exposure… but not “whole body”.

Why Worry, and When?

Informed Consent *vs.* Public Policy

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Informed Consent *vs.* **Public Policy**

Cost/Benefit Analyses: *Every* public policy decision creates risks. Is this likely to do any good? How much good? Is it likely to do any harm? How much harm? What are the relative probabilities of good and harm? How many people are likely to suffer from the harm? How many people are likely to benefit from the good?

And of course the two questions most popular with politicians, "Which people?" and "When?"

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Any sensible policy regarding radiation hazards, whether public or personal, must take into account that *each of us is going to die*, that our lifespan is frustratingly short no matter what we do, and that our chances of dying of cancer (radiation-induced or otherwise) are already rather high. (About 20%.)

Radiation Units

There is a big difference between a ***little*** and a ***lot***. To make rational distinctions requires *quantitative* measurements, which in turn require well defined and understood **units**.

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Note: the *activity is higher* if the *lifetime is shorter*. (But not for long!)

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REM (R, *R*oentgen *E*quivalent to *M*an):

1 R ≡ *RBE* × **rad**.

(1 mR ≡ *milliREM*] ≡ 10^{-3} R.)

Sievert (Sv) [***S***tandard ***I***nternational unit]:

1 Sv ≡ 100 *REM*

Problems with **DOSE UNITS:**

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No mention of ***over what time*** the dose is *delivered*.

∴ Implicitly *assumed* that DNA damage is ***accumulative***.

Safety standards usually limit mSv *per* ***year***.

But normal cell oxygen metabolism also causes DNA DSB…

…and most DNA DSB ***heal*** within ***hours***.

Meanwhile, a healthy ***immune*** system is constantly eliminating lone cancer cells.

Still, the rare ***permanent*** DSB may occur, and under constant irradiation the number of such defects ***does*** accumulate.

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- **Sub-Acute Exposures**: ~ **1** Sv whole-body delivered all at once → no immediate symptoms, but possible leukemia (rarely, years later).

EFFECTS, cont'd

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Different body parts have dramatically different resistance to radiation.

Hands can withstand radiation doses that would *kill* if delivered to the whole body.

The ***lens of the eye*** and the ***gonads*** are considered to be the *most vulnerable*.

There is some evidence (*e.g.* from Ramsar and Kerala) for ***radiation hormesis*** (marginal exposures may actually *promote better health*).

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- **Cosmic Rays**:

  Sea level: 30-40 mR/y
  Colorado: 120 mR/y
  At 40,000 ft: 0.7 mR/*hour*.
  (One average round-trip transcontinental flight gives 6-8 mR)

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  γ-radiation is fairly uniform in the U.S.A., ranging from 30 mR/y in Texas to 115 mR/y in South Dakota. (Guess where the uranium deposits are!)

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See also **xkcd chart**

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Many radionuclides (radioactive isotopes) emit fast α particles (^{4}He nuclei). The range of most α "rays" is only ~ cm in air and ~ mm in tissue. ***Good*** if they are at arm's length; ***bad*** if you swallow them or breathe them! A wide variety of radioactive elements have assorted chemical properties, each with a specific hazard.

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- **Radon**: All rock contains some *radium* which decays, releasing the chemically inert noble gas *radon*, itself a radioactive element which emits a low energy α (difficult to detect). Radon probably killed Madame Curie. Widespread and dangerous because it accumulates in the air of any building made of rock, brick or concrete (especially those with closed air circulation) and thence in the lungs of the people breathing that air, who become radioactive (easy to detect).

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  Different regions have a huge range of radium content, so a stone house may be perfectly safe in one place and hazardous in another.

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- **Man-Made Radionuclides**: Formerly most famous: *plutonium*, ^{239}Pu, of which fission bombs are made. A deadly chemical poison as well as a nasty radioisotope, a miniscule grain caught in your lungs or other tissues exposes (only) nearby tissue to a huge dose. Newly famous: *polonium*, ^{210}Po, is made in reactors by adding neutrons to bismuth. It is an even deadlier poison.

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In the 1960s we could detect parts per million (**ppm**) of Selenium (**Se**), a heavy metal which is *poisonous* at that concentration. The US Congress then passed a law making it illegal for any foodstuffs to contain a ***detectable*** amount of Se. A few years later we were able to detect parts per billion (**ppb**). That's when we discovered that Se is an ***essential mineral***. This illustrates the foolishness of any policy of "**zero tolerance**".

Protection Against Radiation

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Best shielding is ***Gauss' Law***: intensity $\propto 1/r^2$.

Localized sources are labelled with their activity *at a given distance*, for instance “10 mr/h at 1 m”.

Never *touch* a source! ($1/r^2 \to \infty$ as $r \to 0$).

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Localized sources are labelled with their activity *at a given distance*, for instance “10 mr/h at 1 m”.

Never *touch* a source! ($1/r^2 \to \infty$ as $r \to 0$).

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For *ingested radionuclides*, ***chelation*** can sometimes help. In the case of *tritium* (^{3}H), one should drink lots of ***beer!***