Nanonetworks. Connectivity analysis in Biomedical Applications (blood flow)

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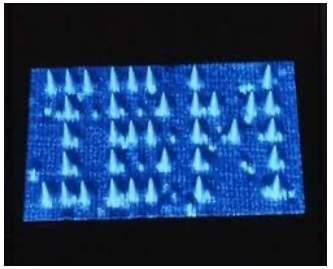
MOTIVATION

“Plenty of Room at the Bottom”

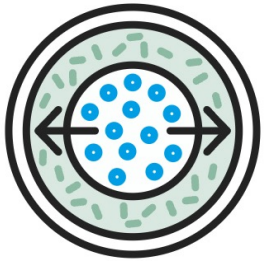
- In 1959, physicist **Richard Feynman** described how the manipulation of **individual atoms** and molecules would allow **more functional and powerful human-made devices**

https://learn.genetics.utah.edu/content/cells/scale/

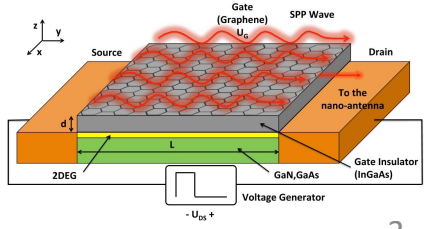
- **Nano-technology**
  - The scanning tunneling spectroscopy concept allows the placement of individual atoms
    - The logo of IBM was writen at the atomic level in 1989
    - A magnetic memory bit was made of just 12 atoms by IBM in 2013



- **Targeted Drugs** (nano particules)
  - Nano devices spreading over the human body can monitor the human physical movement.
  - Targeted therapy uses drugs to target specific areas of the body.

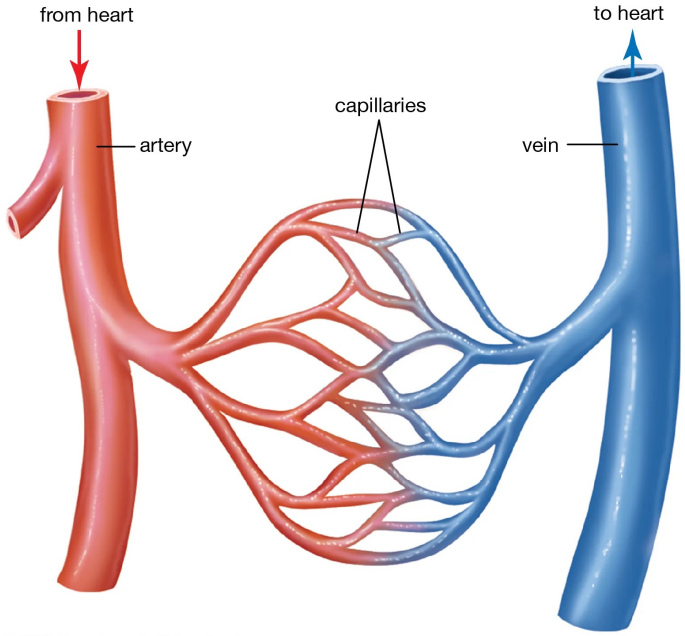


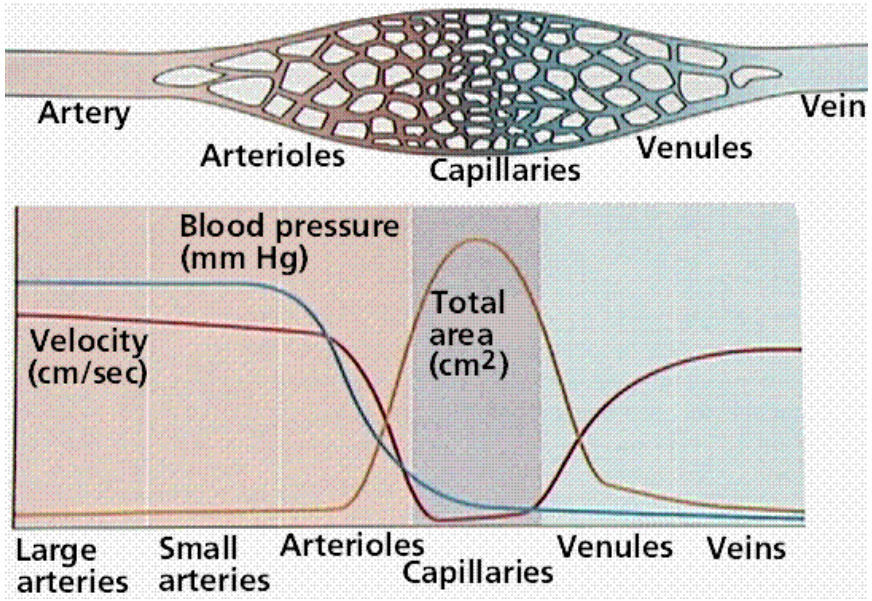
- **Nano-communications**
  - Nanomachines also require nano transceivers and antennas.
  - This ranges from the THz band to the infrared and visible optical frequency



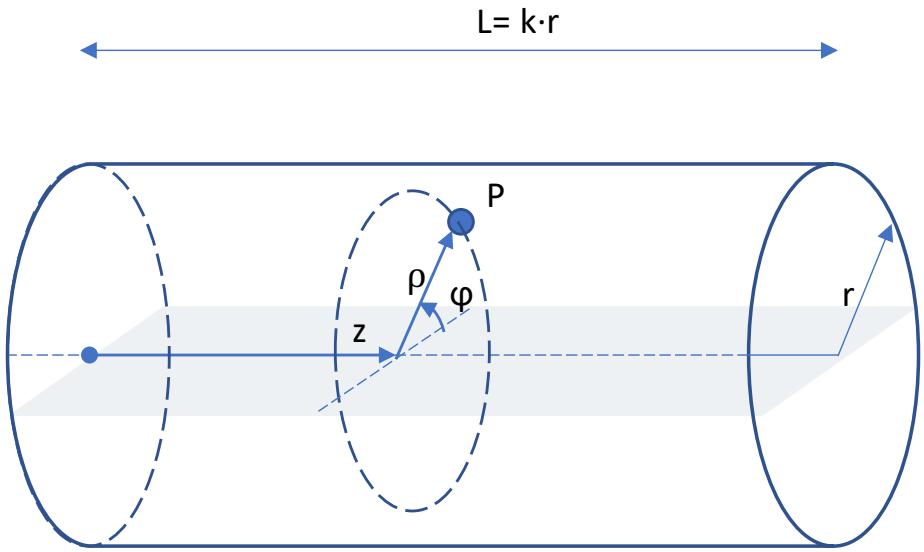
Modelling circulatory system and blood flow

- 84% of the body's total blood volume is in the circulatory system (systemic circulation).
  - 64% in the veins, 13% in the arteries and 7% in the systemic arterioles and capillaries



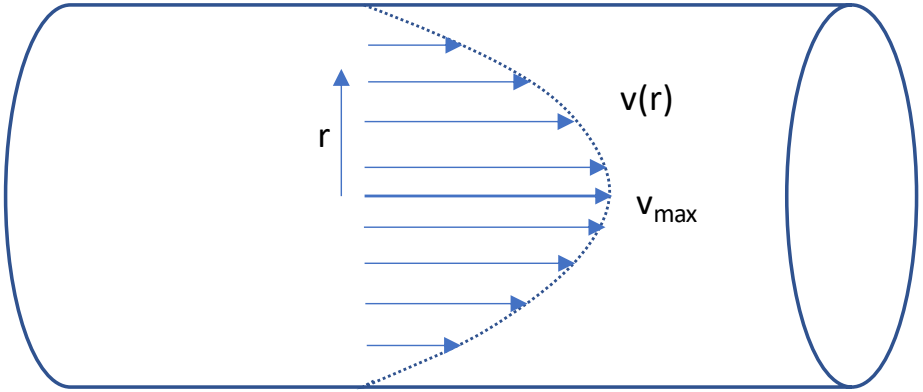


Modelling the circulatory system. Vessel

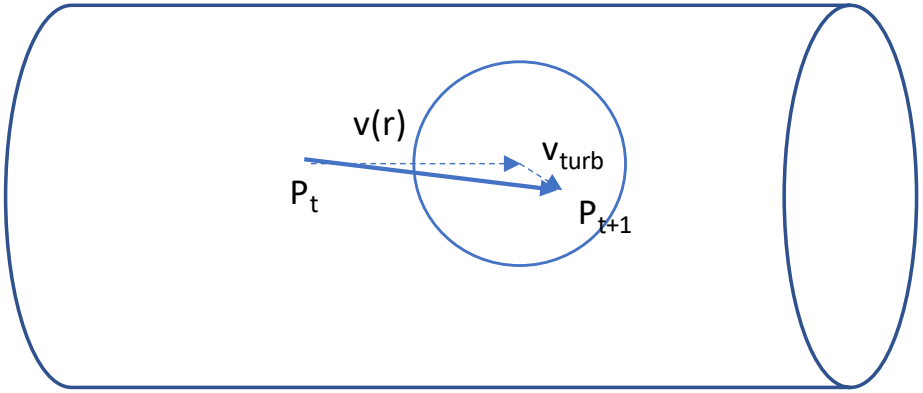


Cylindrical coordinate system. The coordinates (ρ, φ, *z*) of a point *P* are: ***ρ*** *,* the *axial distance* (or *radial distance)* from the *z*-axis to the point *P;* ***φ*** (*azimuth*), the angle between the reference direction on the chosen plane and the line from the origin to the projection of *P* on the plane, and ***z*** (the *axial coordinate,* or *height),* the distance from the chosen plane to the point *P*.
Wikipedia

Modelling the circulatory system. Blood flow

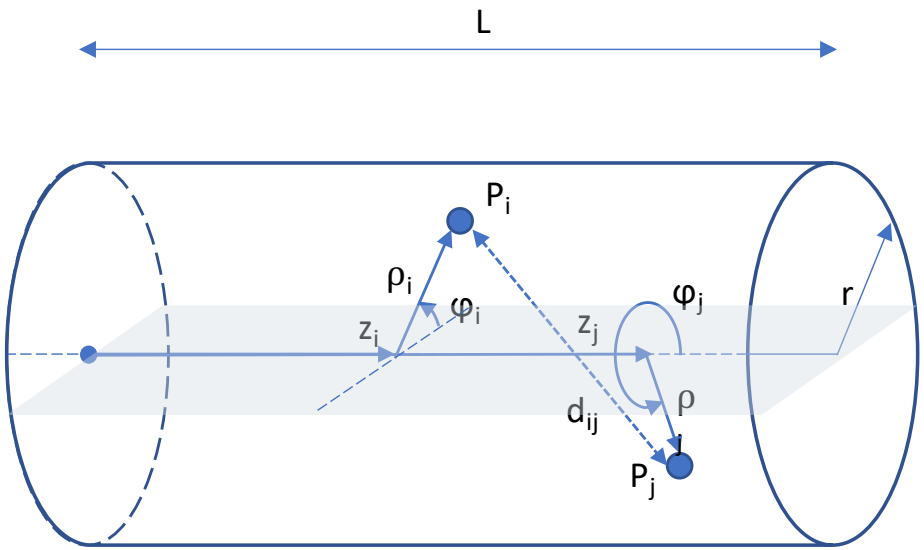


Laminar Flow



Turbulent Flow

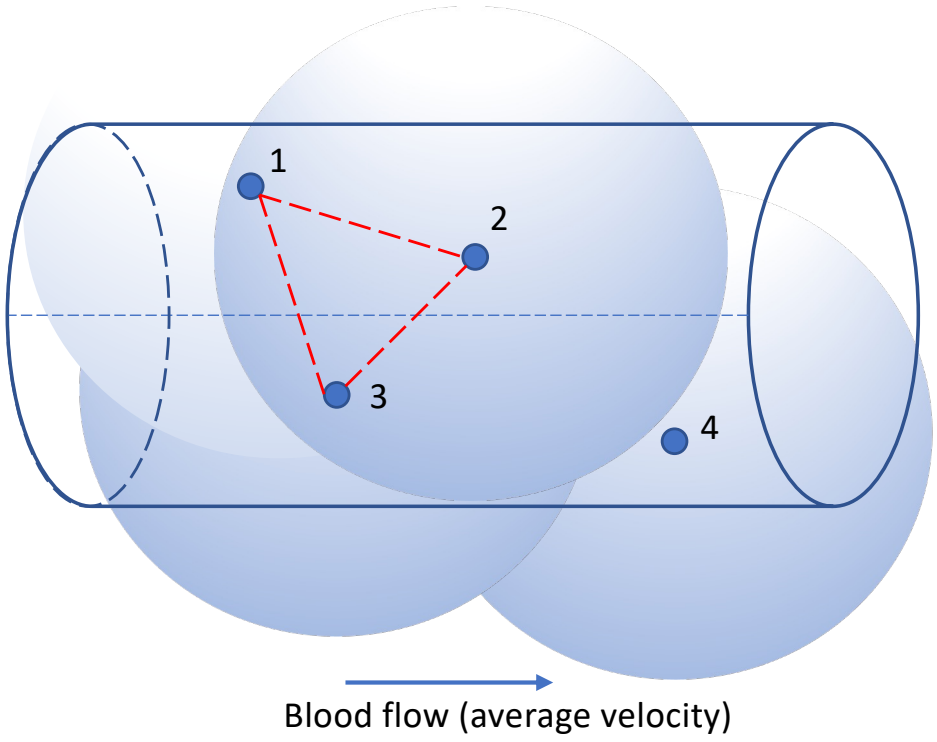
Modelling the circulatory system. Connectivity (i)

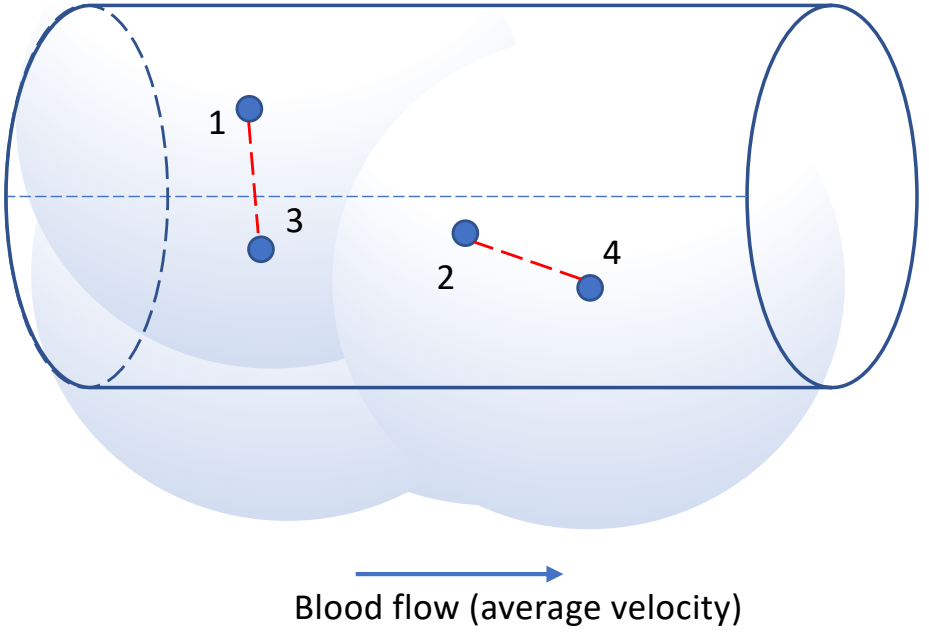


Ro ρ φ z

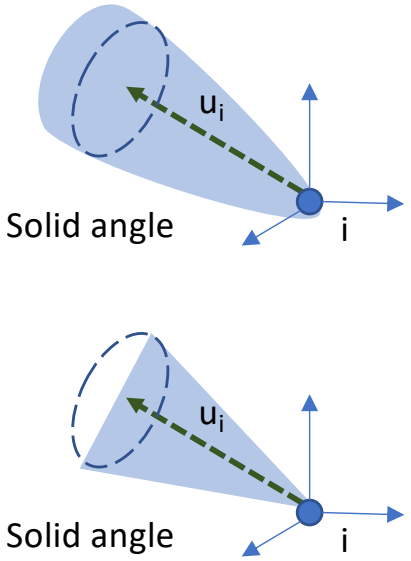
X= ρ cos φ
Y= ρ sin φ
Z = z

Modelling the circulatory system. Connectivity (ii)

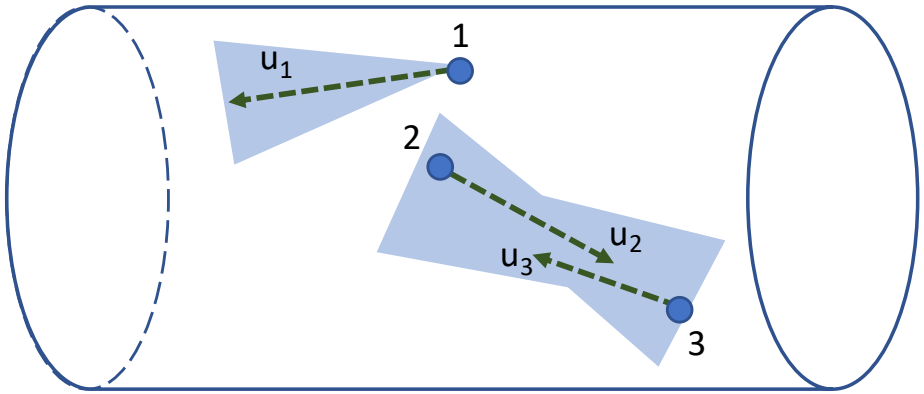




Modelling the circulatory system. Optical directional, connectivity.

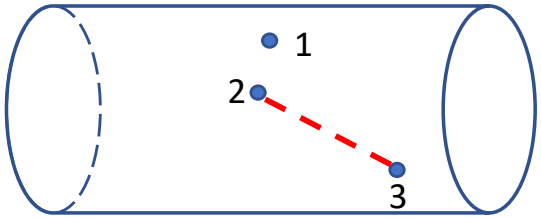


Optical directional range ≈ 10 mm)



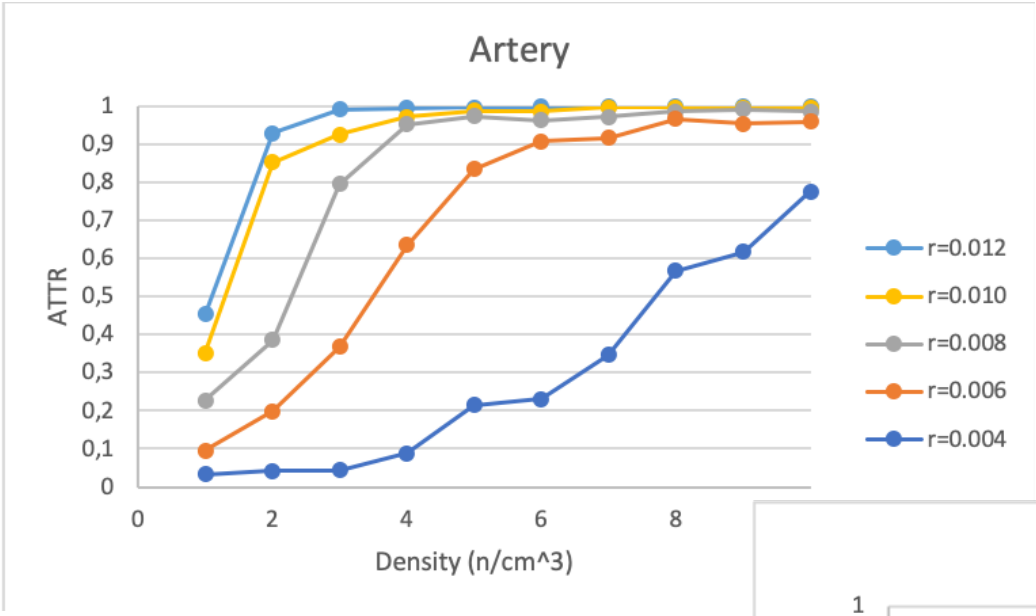
The connectivity is more difficult, on top of being in range the orientation of the and the best case is the establishment of pairs (ATTR is not used).

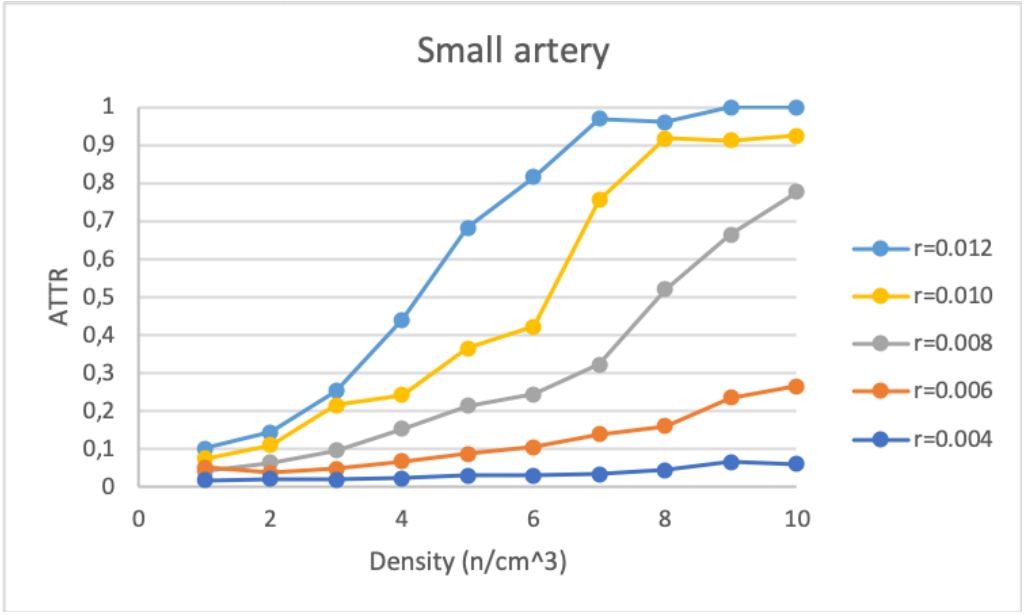
Once a pair is established, both nanorobots are not considered anymore. Imagine a 4th nanorobot between 2 and 4 and well oriented (for instance facing 3) this case communication 3-4 is not is not considered.



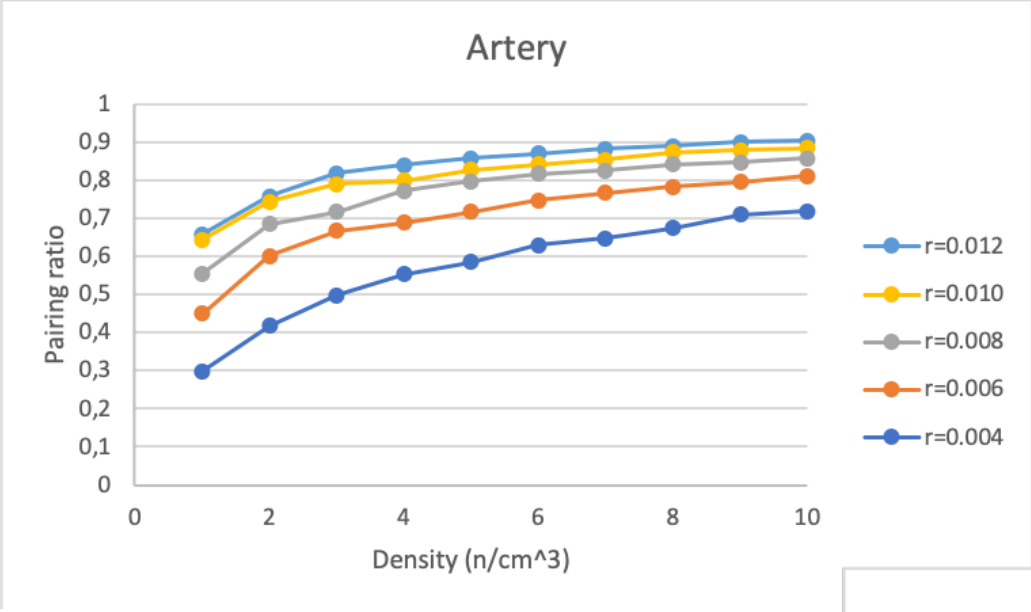
For simplicity of the model, the actual orientation is not tracked, instead a probability of remain connected is used.

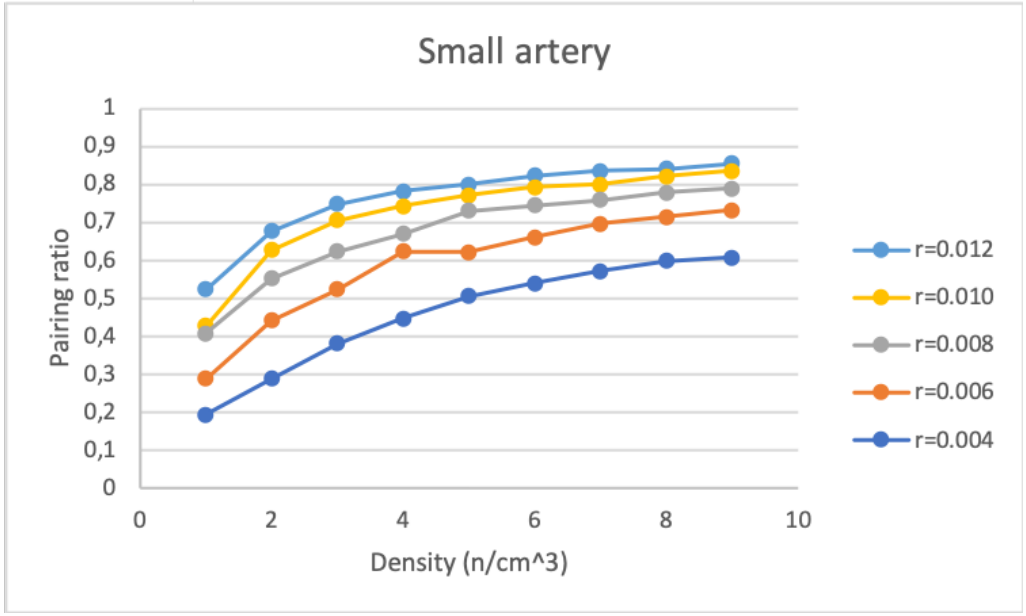
Preliminary results: EM (THz) Omnidirectional





Preliminary results: Optical Directional





Conclusions

- **Range** and **density** are the most rellevant parameters
- As the **diametre** of the vessel decreases the topology of the network is modified (the diametre of the graph increases) making more difficult the connectivity.
- **Small vessels** (including capillarity) present very small volumen (of blood) hence **connectivity is almost impossible**
- **Turbulence** ratio and average **velocity do not modify** substantially the results

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Q?

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