Introducing ICRP Publication 145!

Introduction to Mesh-type Reference Computational Phantoms

Limitations of Voxel Phantoms & Tetrahedron Mesh Geometry

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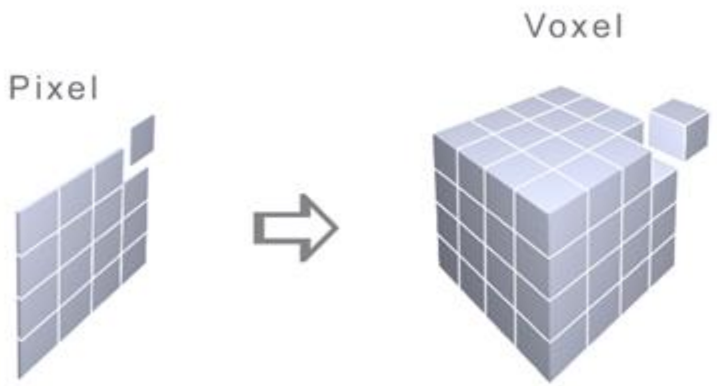
Member, ICRP Committee 2
Chair, ICRP Task Group 103

ICRP Webinar, 17 January 2023

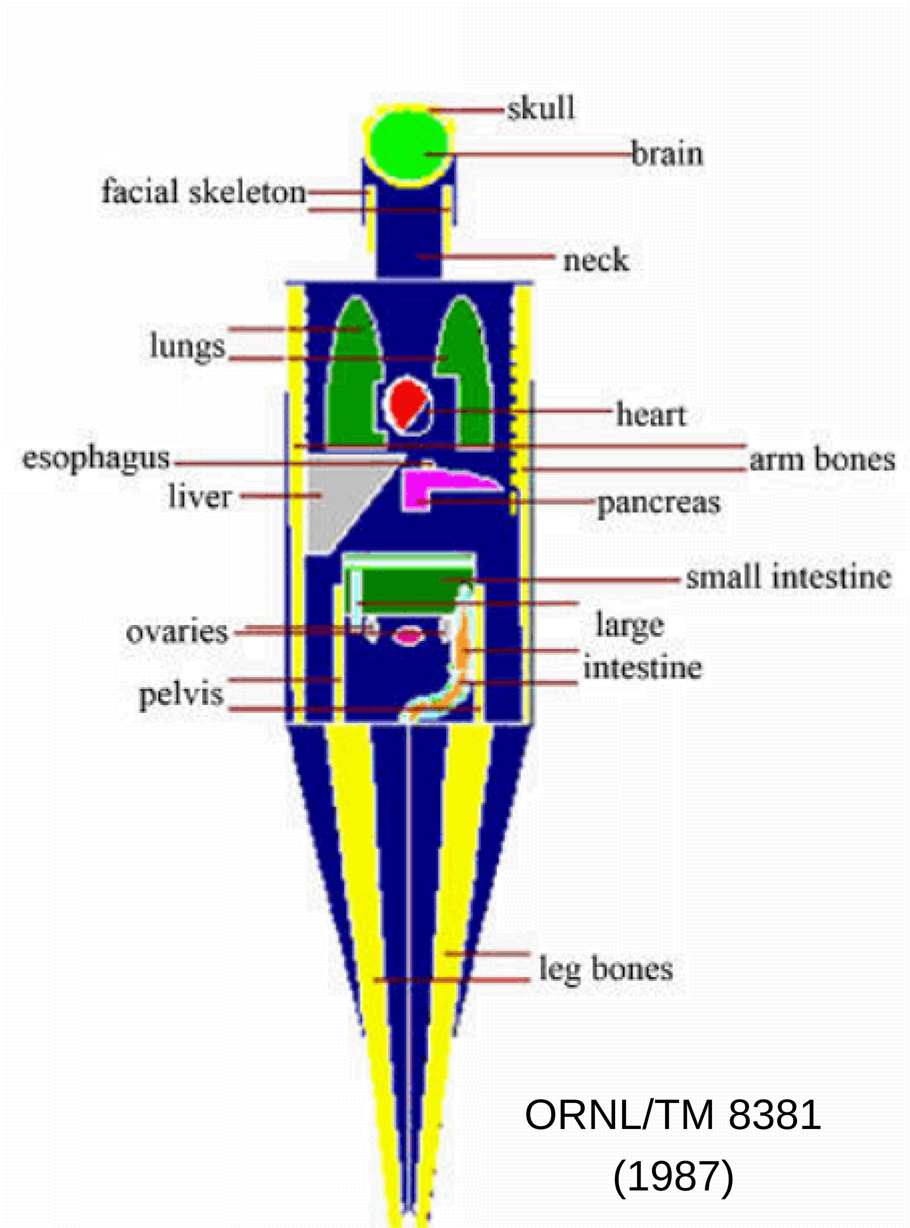
What Is Voxel?

"Voxel" = "Volume" + "Pixel"

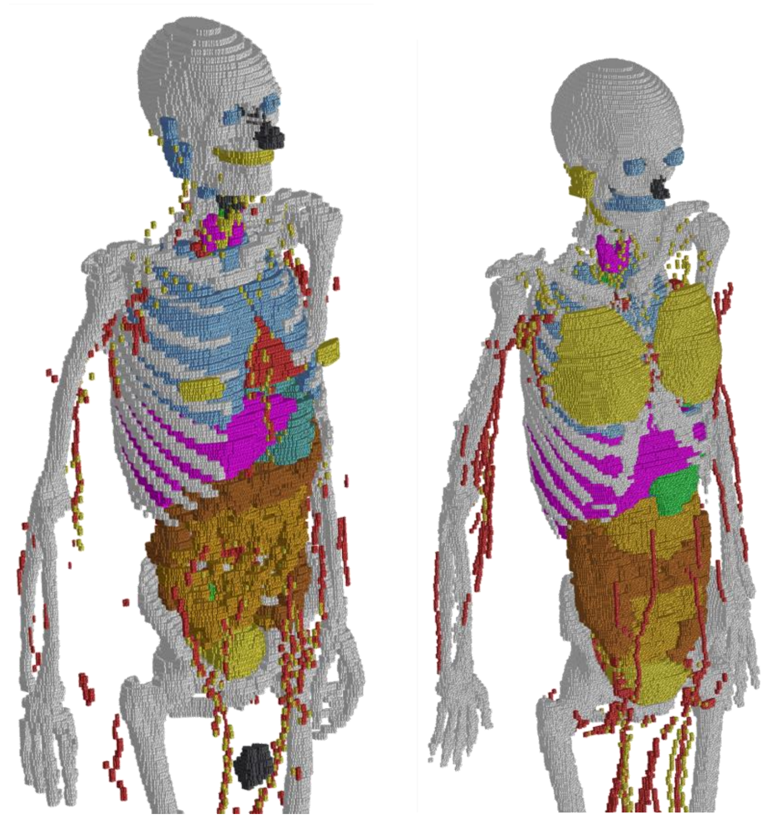


- Limitations:
  - Very difficult to construct a model with thin layers or small structures
  - Not deformable
  - Jagged stair-stepped surfaces

Computational Phantoms Used in ICRP

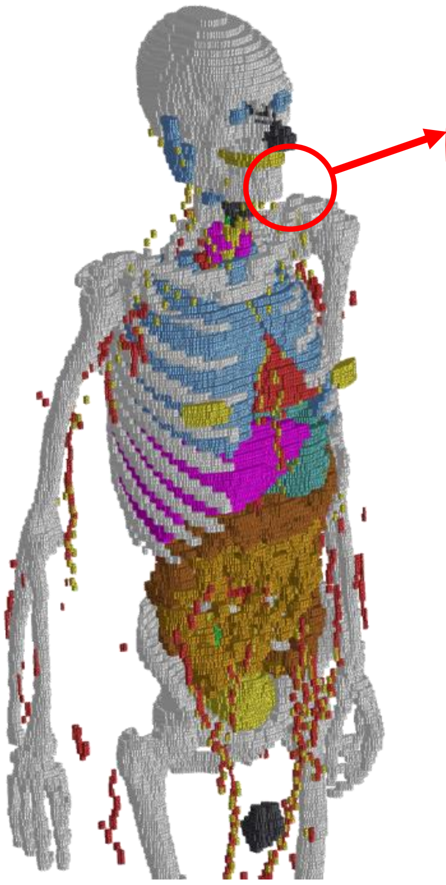


ORNL/TM 8381
(1987)

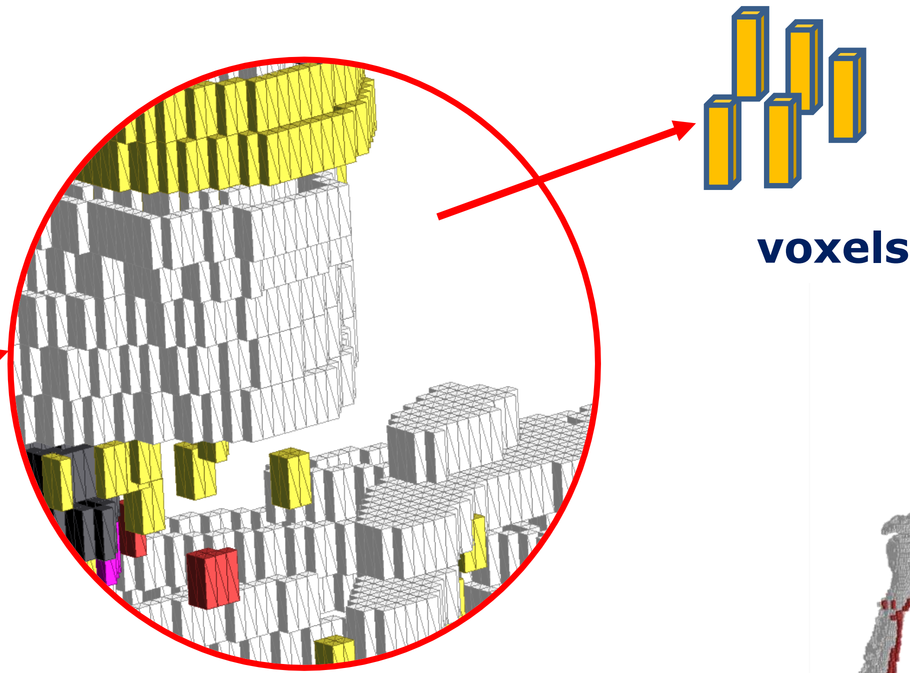


ICRP Publication 110
(2009)

Limitations



Male phantom
(2.137×2.137×8 mm³)

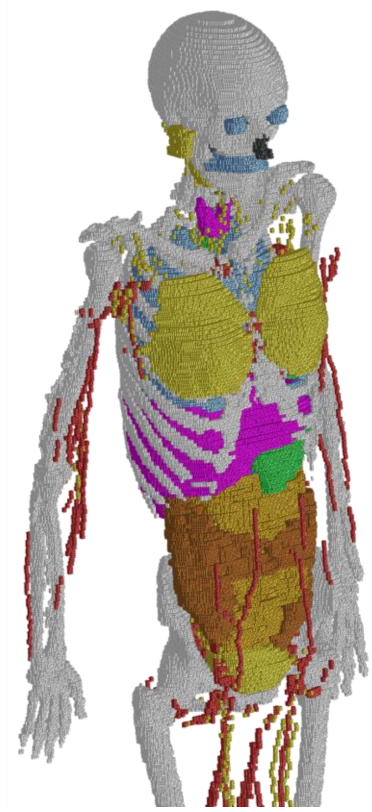


Jagged stair-stepped surfaces, not fully closed

Thin/tiny structures cannot be represented (e.g. stem cell layers)

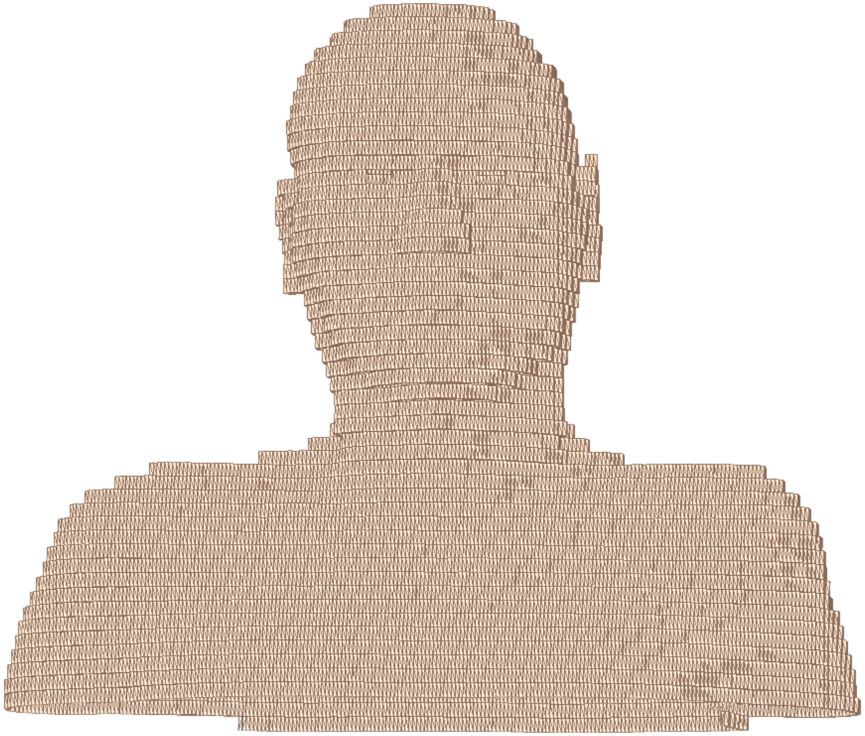
⇩

Necessity to use 12 additional stylised phantoms for dose coefficient calculations

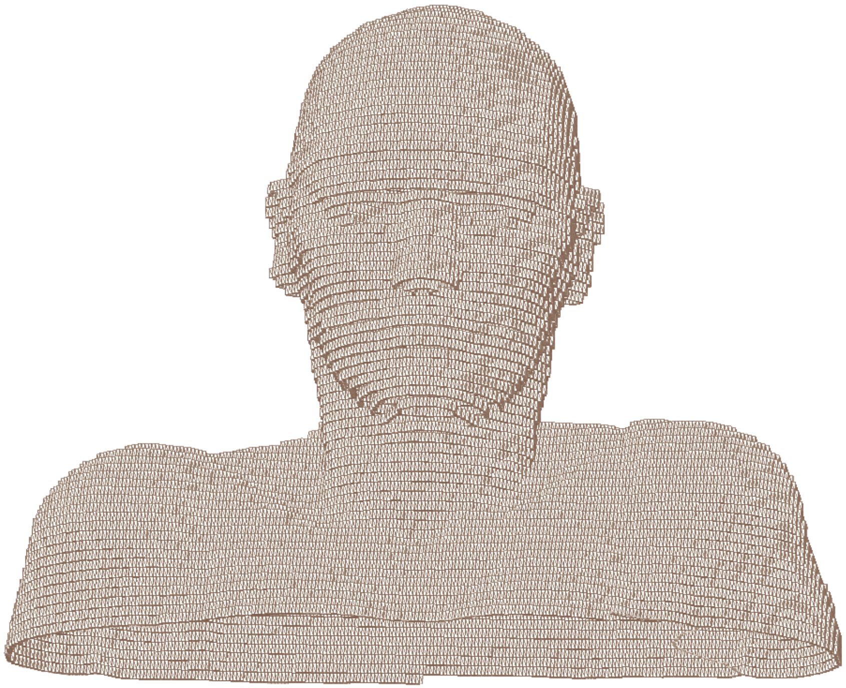


Female phantom
(1.775×1.775×4.8 mm³)

Limitation #1 (Skin)



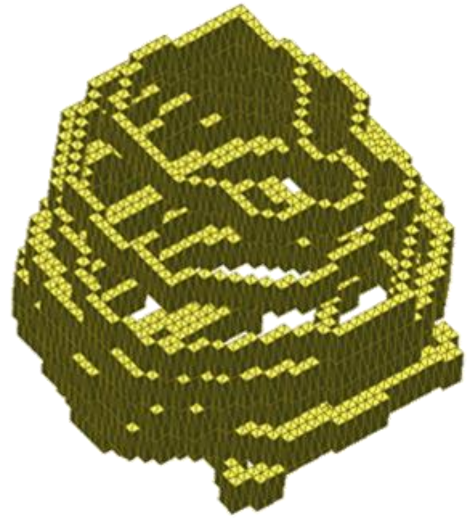
ICRP reference male phantom
(2.137 × 2.137 × 8 mm^3)



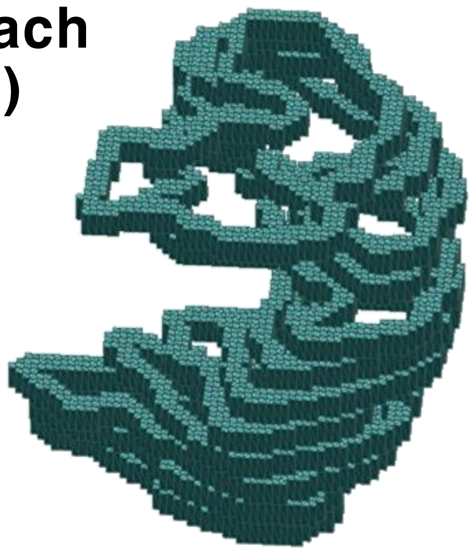
ICRP reference female phantom
(1.775 × 1.775 × 4.8 mm^3)

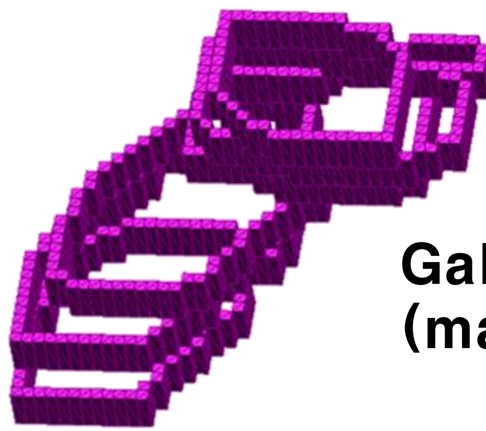
Limitation #2 (Hollow Organs)

Urinary bladder
(male)



Stomach
(male)

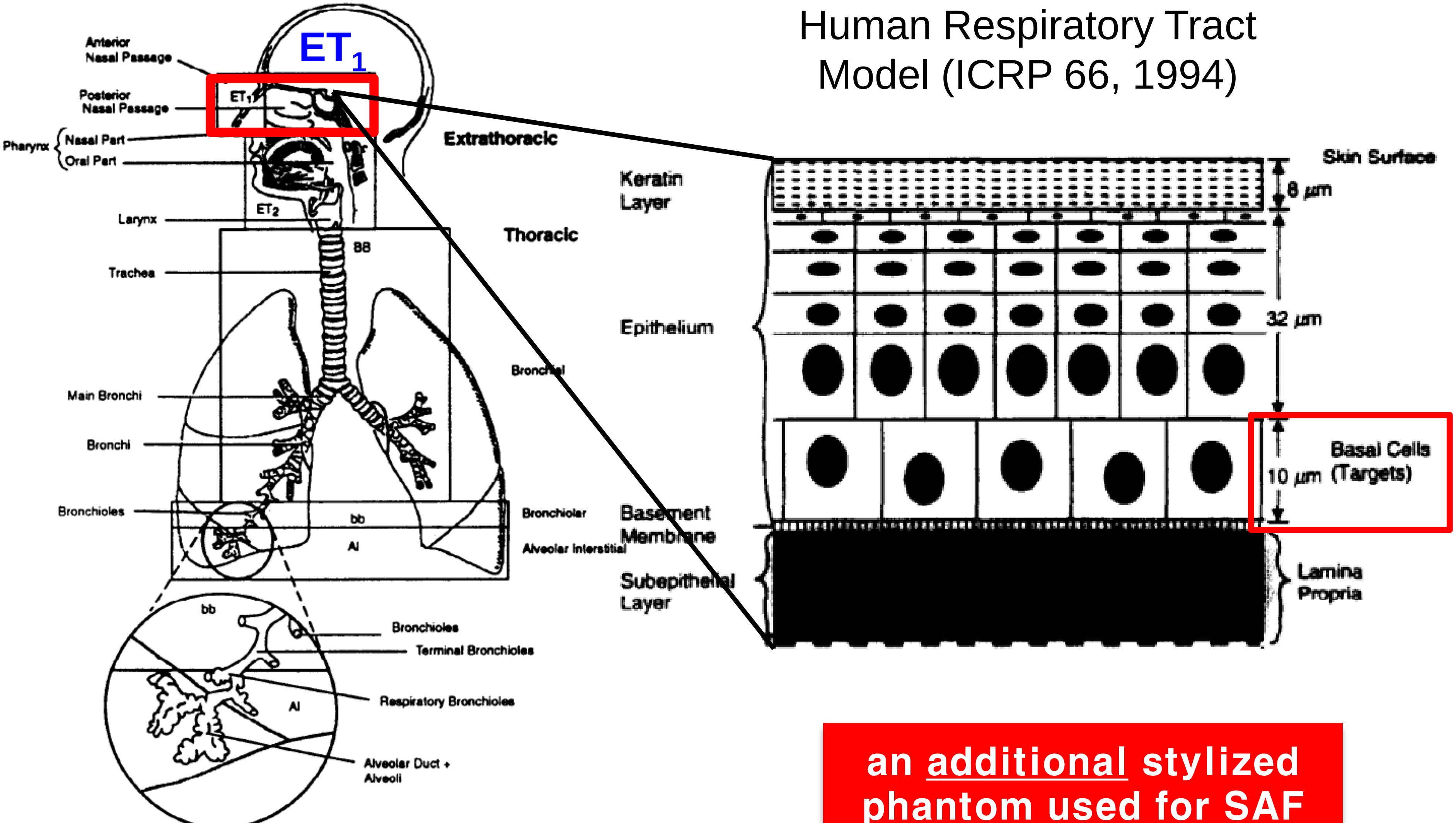




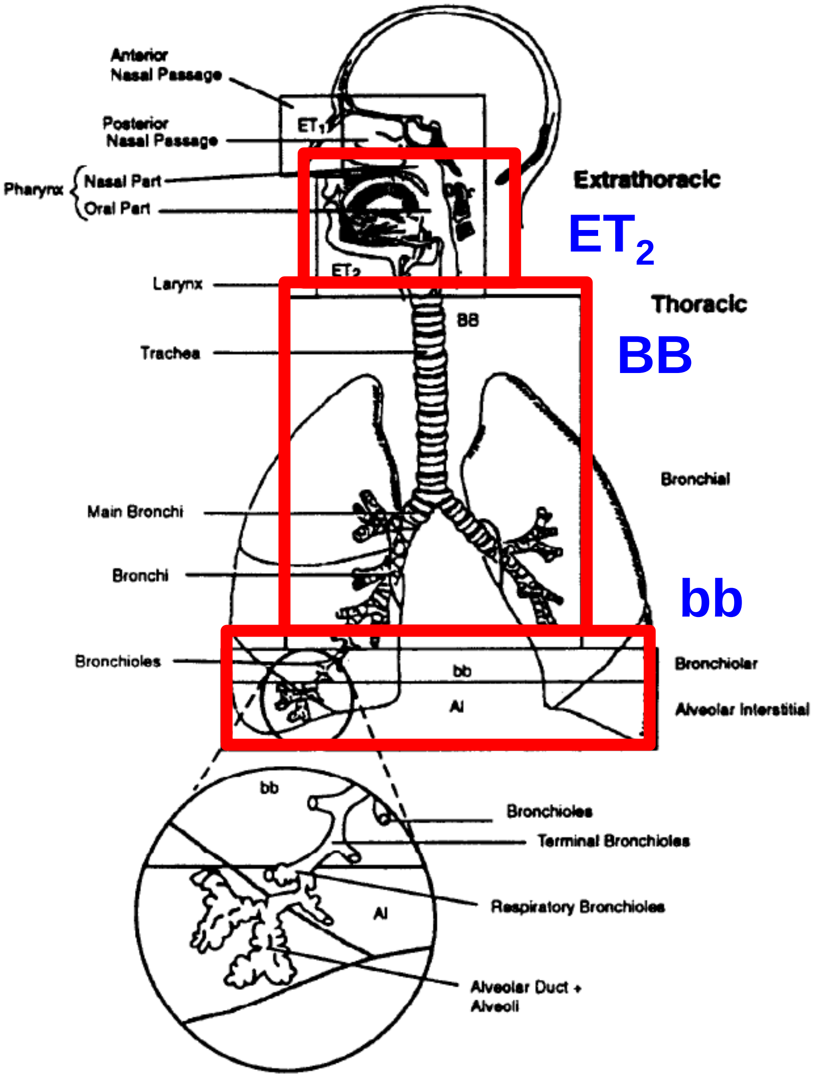
Gall bladder
(male)

Limitation #3 (Respiratory Tract Organs)

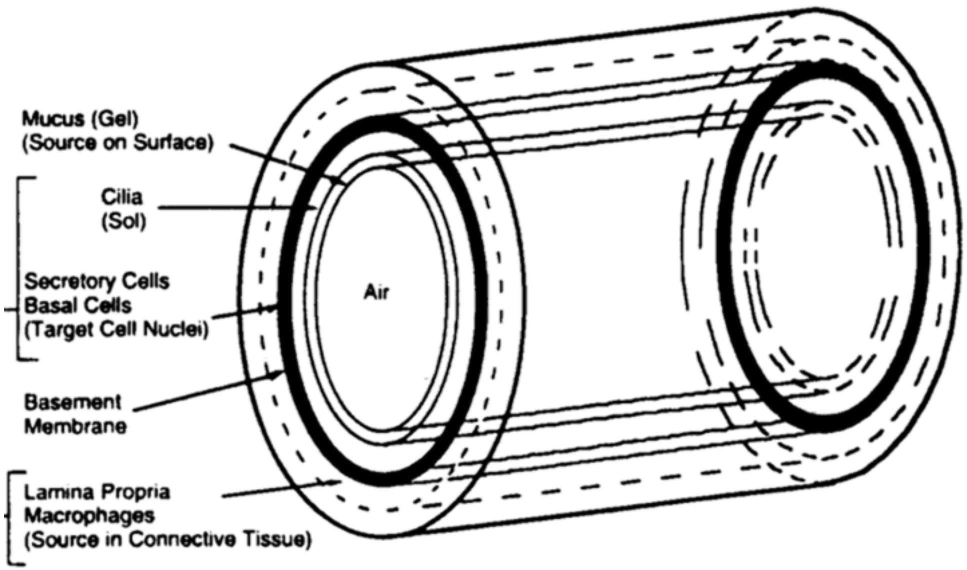
Human Respiratory Tract Model (ICRP 66, 1994)



an <u>additional</u> stylized phantom used for SAF calculations

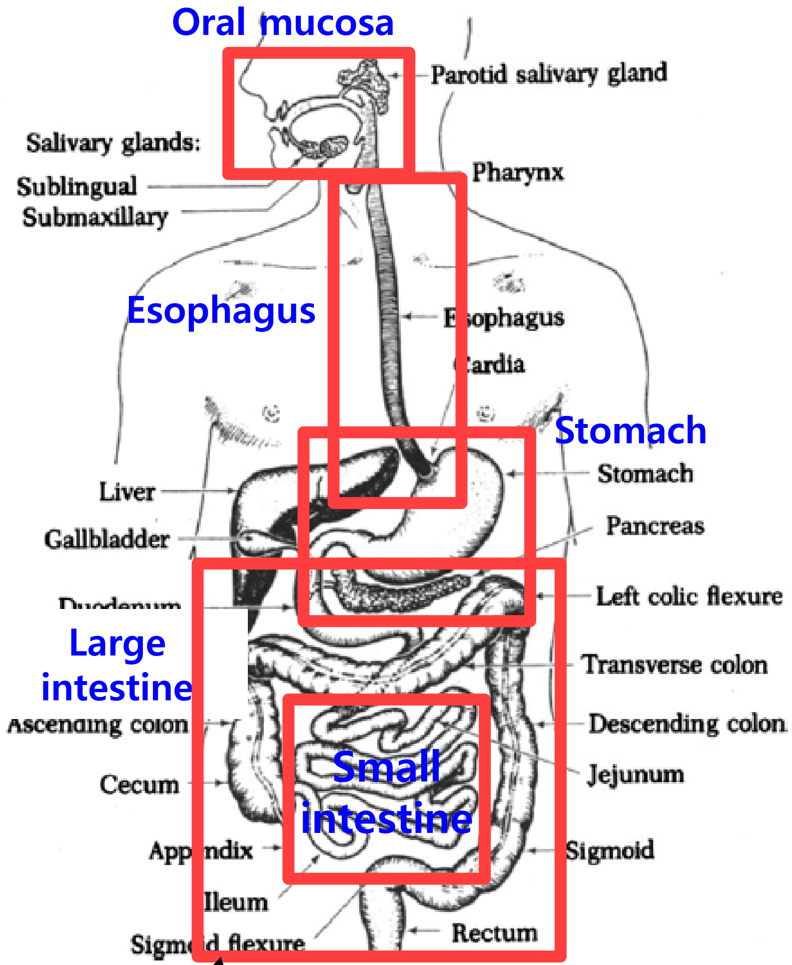


ICRP 66, 1994

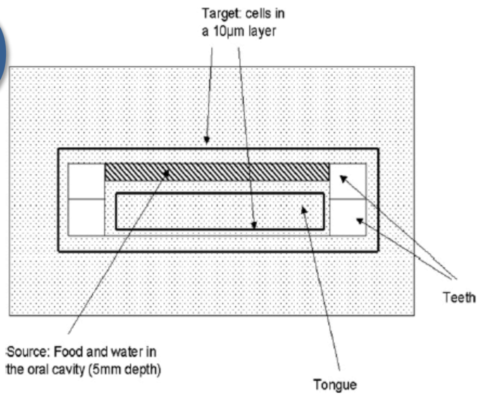


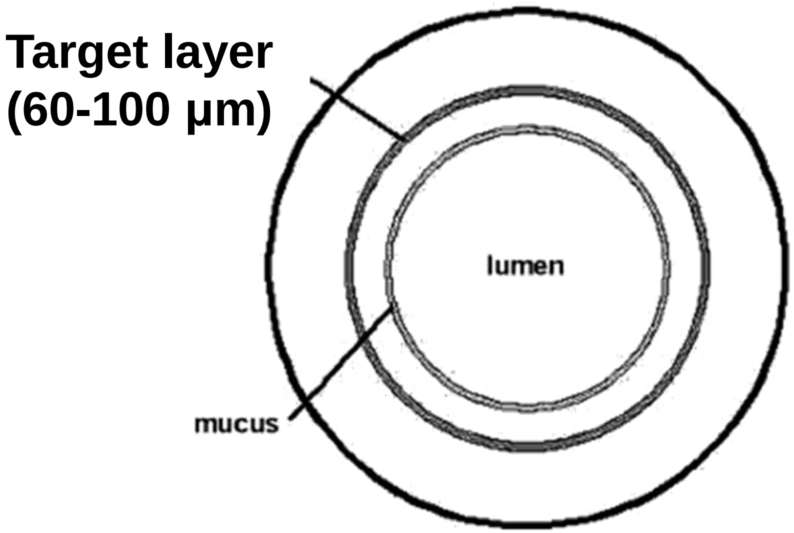
3 additional stylized phantoms used for SAF calculations

Limitation #4 (Alimentary Tract Organs)



Note: 3 different stylized phantoms are used for large intestine.



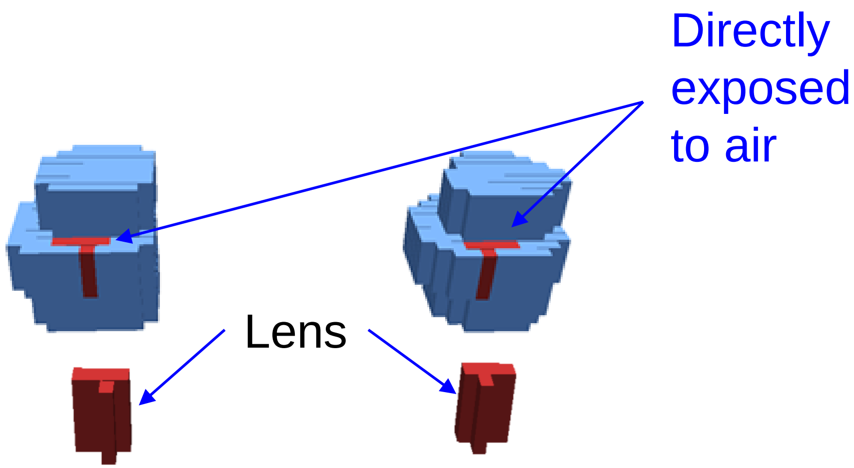


Human Alimentary Tract Model (ICRP 100, 2006)

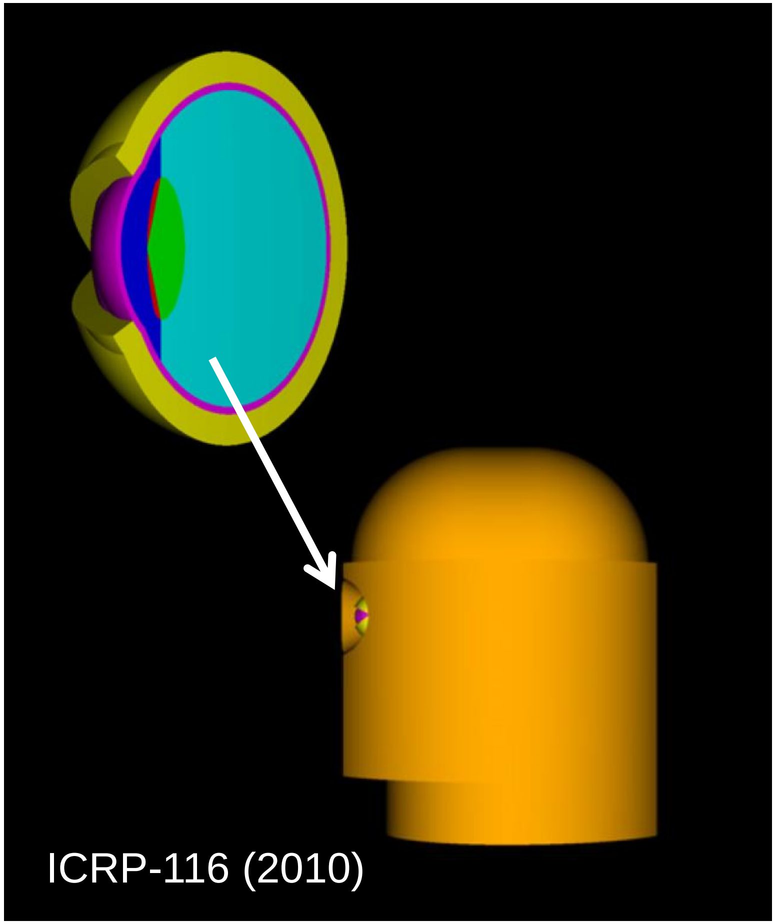
7 additional stylized phantoms used for SAF calculations

Limitation #5 (Eye)

- The lenses of the eyes are directly exposed to air, which is anatomically incorrect, resulting in significant overestimation in lens dose calculation for weakly-penetrating radiations.



Eye models of ICRP-110 male pha ntom



"Using *12 additional stylized phantoms*"

Other Limitations

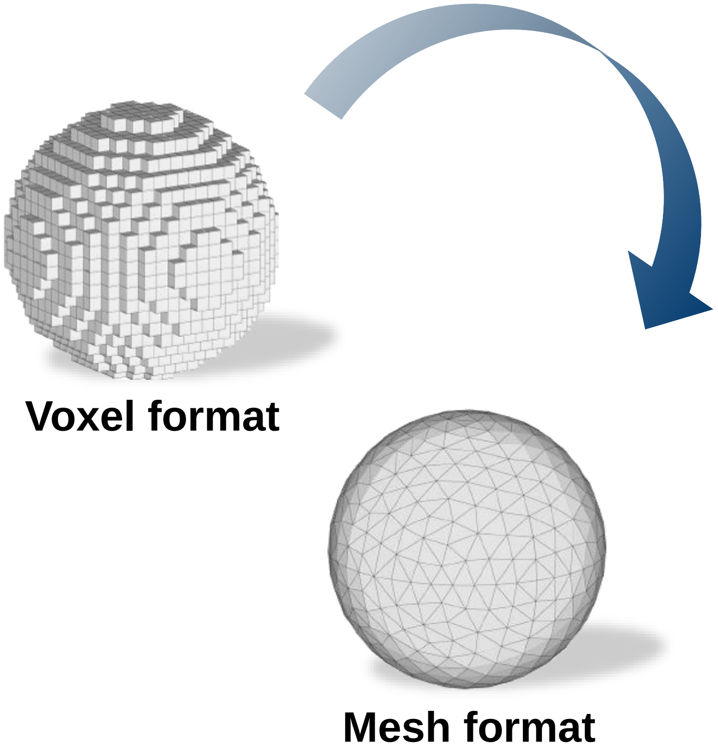
- The ICRP Publication 110 phantoms were matched to the reference organ masses ***exclusive of blood content***.
  - Organs smaller than usual (i.e., by 3-20%)
  - Some neighboring organs not in contact
- These phantoms are ***not deformable***.
- Some spongiosa is not fully covered by cortical bone.
- Some cartilage is included in spongiosa.
- The sacrum of the female phantom does not have cortical bone.
- The distribution of lymphatic nodes in the phantoms are not symmetric.
- Some tissue masses do not match the ICRP-89 data

Limitations Discussed in ICRP C2 Meeting

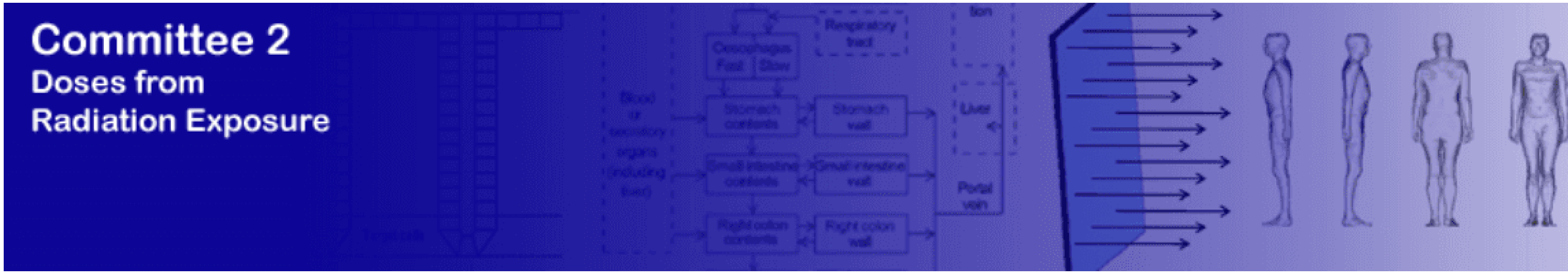
(Abu Dhabi, UAE October 2013)

- The committee decided to convert the voxel-type reference computational phantoms into a high-quality mesh format to address these problems.

- The new phantoms will replace the current voxel-type reference phantoms from the next set of general recommendations.



Task Group 103 (2016)



- Main Commission
- Scientific Secretariat
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- Committee 2 Doses from Radiation Exposure
- Committee 3 Protection in Medicine
- Committee 4 Application of the Commission긎 Recommendations
- Committee 5 Protection of the Environment
- Emeritus Members
- Full ICRP Membership List
- ICRP and Fukushima
- Formal Relations with other Organisations
- ICRP Funding

You are here: ICRP Activities > Task Group 103

Task Group 103
Mesh-type Reference Computational Phantoms (MRCP)

The mandate for this Task Group - Mesh-type Reference Computational Phantoms (MRCP) - will be focused on converting the current voxel-type reference computational phantoms into a high-quality mesh format to address the limitations of the voxel-type phantoms in some dose coefficient calculations.
Specific work will include:

1. development of mesh-type ICRP reference computational phantoms which have all source and target tissues including the details of the eyes and skin and the thin target tissues (10-300 micron) of the alimentary and respiratory tract organs,
2. use of these mesh-type phantoms to calculate external and internal dose coefficients to estimate the uncertainties of the current reference dose coefficients, especially for the dose coefficients calculated with stylized phantoms (eye lenses, skin, and alimentary and respiratory tract organs) for weekly penetrating radiations, and
3. demonstration of phantom posture change and related dose coefficient calculations.

Chair

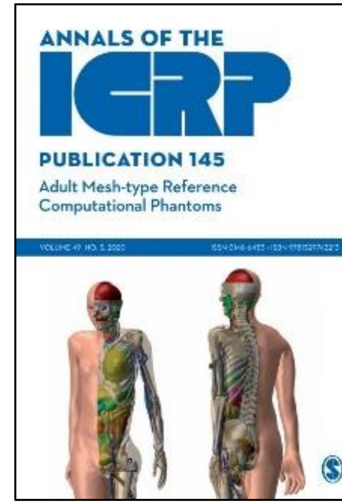
Prof Chan Hyeong Kim

Initial Membership of TG 103

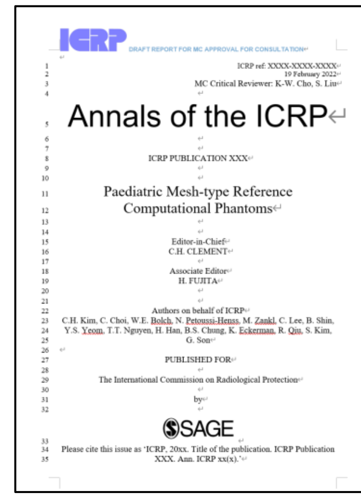
1. Chan Hyeong Kim (Hanyang Univ., Korea, ICRP C2) - *Chair*
2. Yeon Soo Yeom (NCI, U.S.A)
3. Maria Zankl (HMGU, Germany)
4. Nina Petoussi-Henss (HMGU, Germany, ICRP C2)
5. Wesley Bolch (Univ. of Florid, U.S.A, ICRP C2)
6. Choonsik Lee (NCI, U.S.A)
7. Keith Eckerman (ORNL, U.S.A)
8. Riu Qiu (Tsinghua University, China)
9. Bum Sun Chung (Ajou Univ., Korea) – M.D./anatomist
10. Chansoo Choi (Hanyang Univ., Korea)
11. Min Cheol Han (INFN, Italy)
12. Han Sung Kim (KIRAMS, Korea)
13. Tat Thang Nguyen (Hanoi Institute of Technology, Vietnam)

Current Status

- Adult phantoms
  - Phantoms completed
  - Report published (*Publication* 145, 2020)



- Pediatric phantoms
  - Phantoms completed
  - Report completed
    - ✓ Public consultation completed
    - ✓ Will be published soon



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Annals of the ICRP

ICRP PUBLICATION XXX

Paediatric Mesh-type Reference Computational Phantoms

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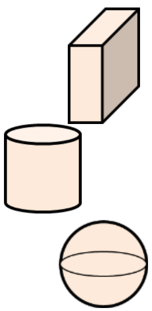
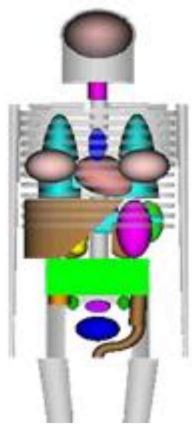
- Pregnant-female phantoms
  - Phantoms recently completed
  - SAF values will be calculated (~a few months)
  - Report will be published in early 2024

Advances in Phantom Geometry

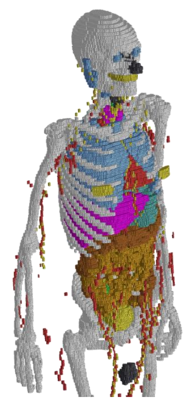
1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)	4th Generation (2100s~)
Simplified	**Stylized (Equations)**	**Voxel**	**NURBS/Polygon Mesh**	**Tetrahedrons Mesh**





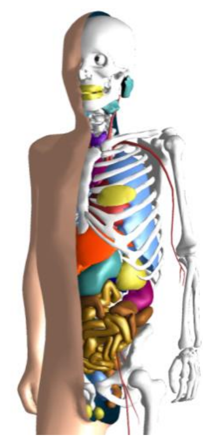
MIRD5,
ADAM/EVA,
KMIRD, …

- Not realistic



ICRP 110,
VIP-MAN,
HDRKs, …

- Not deformable
- Stair-stepped
- No thin/tiny tissue



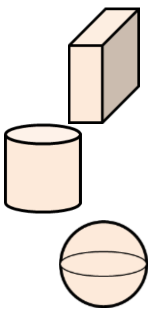
PSRKs,
UF Family,
RPI-AM,AF
4D XCAT, …

- Deformable
- Voxelization
- No sub-organ density variation

Advances in Phantom Geometry

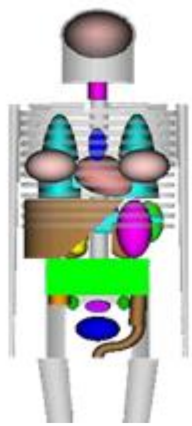
1950s~1960s

Simplified



1st Generation (1960s~)

Stylized (Equations)

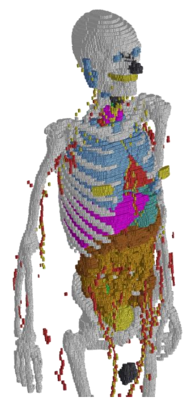


MIRD5,
ADAM/EVA,
KMIRD, …

- Not realistic

2nd Generation (1980s~)

Voxel

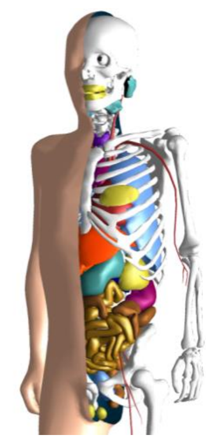


ICRP 110,
VIP-MAN,
HDRKs, …

- Not deformable
- Stair-stepped
- No thin/tiny tissue

3rd Generation (2000s~)

NURBS/Polygon Mesh

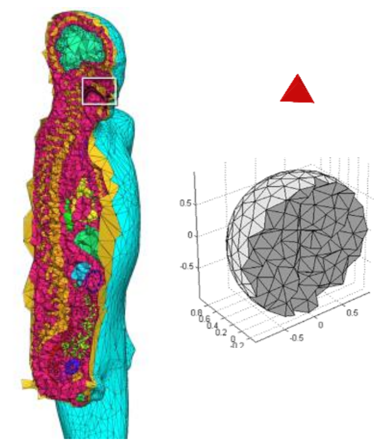


PSRKs,
UF Family,
RPI-AM,AF
4D XCAT, …

- Deformable
- Voxelization
- No sub-organ density variation modeling

4th Generation (2100s~)

Tetrahedron Mesh

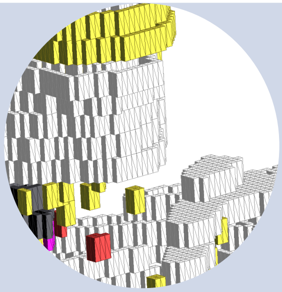
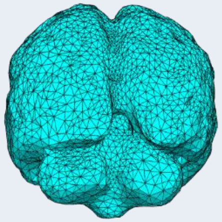


THRKs,
MRCPs,
MRKPs

- Deformable
- No voxelization
- Fast computation
- Sub-organ density variation modeling

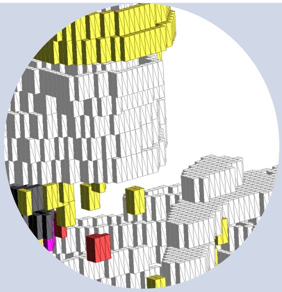
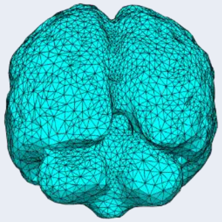
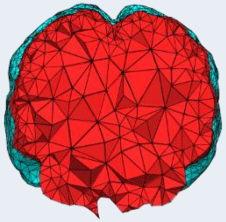
Representation type

Mesh type

	Surface mesh (B-Rep)	Volume mesh (V-Rep)
Structured Mesh		**Voxel** - 2^{nd} generation - Structured volume mesh  <u>Advantages:</u> • Fast simulation • Sub-organ density variation modeling
Unstructured mesh	**NURBS/Polygon mesh** - 3^{rd} generation - Unstructured surface mesh  <u>Advantages:</u> • Flexiblity (deformation) • Precision modeling	

Representation type

Mesh type

	Surface mesh (B-Rep)	**Volume mesh (V-Rep)**
Structured Mesh		**Voxel** - 2nd generation - Structured volume mesh  Advantages: • Fast simulation • Sub-organ density variation modeling
Unstructured mesh	**NURBS/Polygon mesh** - 3rd generation - Unstructured surface mesh  Advantages: • Flexiblity (deformation) • Precision modeling	**Tetrahedron mesh** - 4th generation - Unstructured volume mesh  Advantages: • Flexiblity (deformation) • Precision modeling • Fast simulation (i.e., no voxelization) • Sub-organ density variation modeling

Thank You!