

# HDRK-Man: A Whole Body Voxel Model Based on High-resolution Color Slice Images of a Korean Adult Male Cadaver



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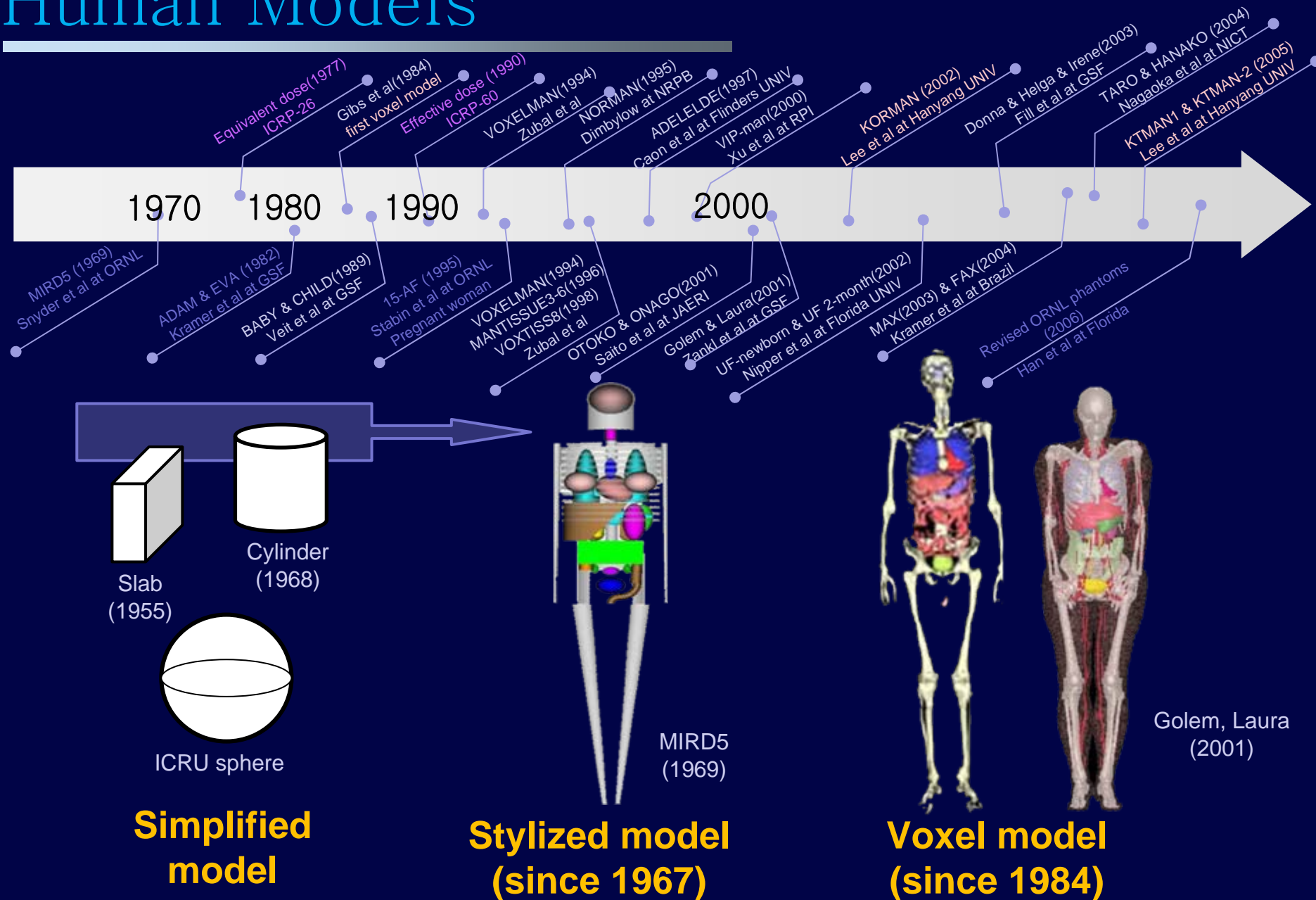
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<sup>3</sup>Ajou University School of Medicine

CMPWG-II, Gainesville, Florida

September 30 – October 4, 2007

# Human Models



# Voxel Models

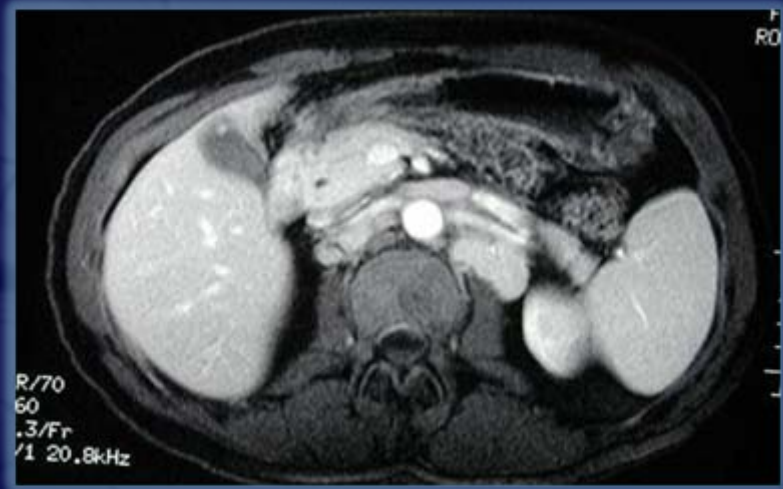
Model	Images	Subject	Race	Age and gender	Voxel size (mm <sup>3</sup> )	Comment
BABY	CT	Cadaver	Caucasian	8-week-old female	2.90	
CHILD	CT	Leukemia patient	Caucasian	7-year-old female	19.00	
Zubal Phantom	CT	Diffuse melanoma	Caucasian	Adult male	46.70	Head and torso
NORMAN	MRI	N/A	Caucasian	Adult male	8.10	
ADELAIDE	CT	Patient	Caucasian	14-year-old female	64.00	Torso
VIP-man	Photo	Cadaver	Caucasian	38-year-old male (VHP)	0.10	
Golem	CT	Leukemia patient	Caucasian	38-year-old male	34.60	
Otoko	CT	N/A	Japanese	Adult male	9.60	
UF newborn	CT	Cadaver	Caucasian	6-day-old female	0.30	
UF 2 month	CT	Cadaver	Caucasian	6-month-old male	0.30	
Visible-human	CT	Cadaver	Caucasian	38-year-old male (VHP)	4.30	Head to knees
Frank	CT	Patient	Caucasian	48-year-old male	2.80	Head and torso
Donna	CT	Patient	Caucasian	40-year-old female	35.16	
Helga	CT	Patient	Caucasian	26-year-old female	9.60	Head to mid thigh
Irene	CT	Patient	Caucasian	32-year-old female	17.58	
KORMAN	MRI	Volunteer	Korean	30-year-old male	40.00	
MAX	-	N/A	Caucasian	Adult male	46.70	Modified Zubal Phantom
FAX	CT	Volunteer	Caucasian	37-year-old female	46.70	62Y female legs
TARO	MRI	Volunteer	Japanese	22-year-old male	8.00	
HANAKO	MRI	Volunteer	Japanese	22-year-old female	8.00	
Pregnant woman	CT	Patient	Caucasian	30-week-pregnant female	6.20	Lower torso
NAOMI	MRI	Volunteer	Caucasian	23-year-old female	7.82	
UF 9-month	CT	Patient	Caucasian	9-month-old male	0.55	Head and torso
UF 4-year	CT	Patient	Caucasian	4-year-old female	1.01	Head and torso
UF 8-year	CT	Patient	Caucasian	8-year-old female	2.02	Head and torso
UF 11-year	CT	Patient	Caucasian	11-year-old male	1.33	Head and torso
UF 14-year	CT	Patient	Caucasian	14-year-old male	2.34	Head and torso
KTMAN-1	MRI	Volunteer	Korean	25-year-old male	20.00	
KTMAN-2	CT	Volunteer	Korean	35-year-old male	20.00	

# Limitation of CT/MR

- Difficult to delineate some organs
  - ◆ If the organs have similar properties or in continuous movement
  - ◆ Examples – ovaries, pancreas, oesophagus, adrenals, thymus, small intestine, heart, etc.



CT Image



MR Image

# VIP-Man

## ■ Overview

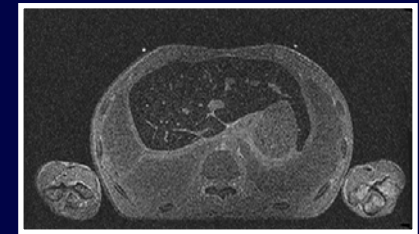
- ◆ Xu et al (2000)
- ◆ Based on color photographic transverse slice images of 38-year-old male
- ◆ The most complete body description
  - Voxel resolution:  
0.33 mm x 0.33 mm x 1 mm

## ■ Limitations

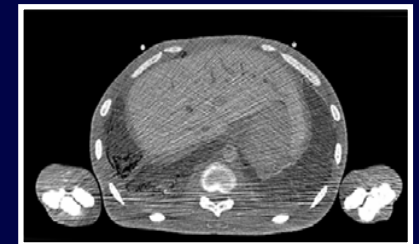
- ◆ Very large (186 cm, 103 kg)
- ◆ Cannot be used to represent the Korean workers (171 cm, 68 kg)



# Objective/Serially Sectioned Images

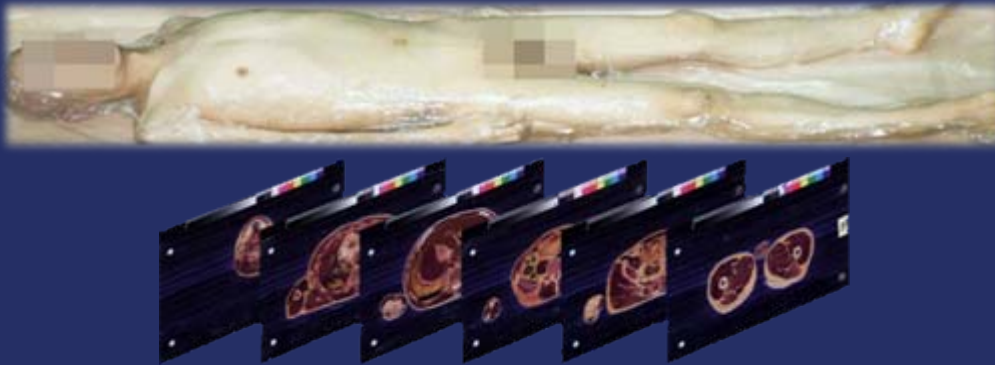


MR  
(1mm x 1mm x 1mm)

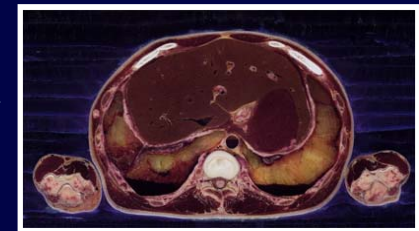


CT  
(1mm x 1mm x 1mm)

Visible Korean Project (VKH)



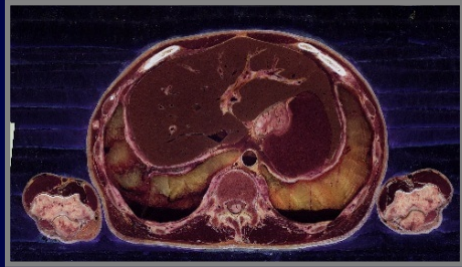
33-years-old, Korean male, 164 cm, 55 kg



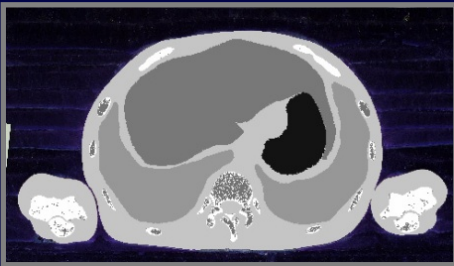
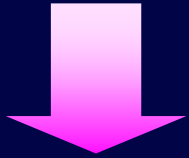
Photographic Image  
(0.2mm x 0.2mm x 0.2mm)



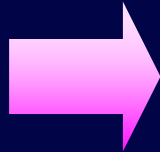
# Steps to Construct Model



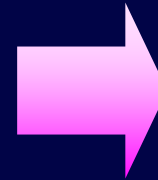
Segmentation



Reconstruction



Adjustment



# Segmentation

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## ■ Vertical Resolution

- ◆ Slice images selected every 2 mm interval – 850 images out of 8,590 images

## ■ Automatic Segmentation

- ◆ Organs and tissues clearly distinguish by color (e.g., eye balls, lenses, RBM, muscle)
- ◆ Photoshop 7.0 Action, IDL 5.6

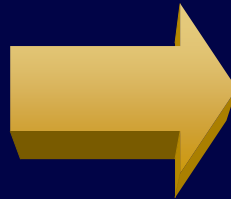
## ■ Manual Segmentation

- ◆ Organs and tissues that could not be segmented automatically (e.g., prostate, pancreas, adrenals, oesophagus, ...)
- ◆ Screen digitizer (CINTIQ 15X) + Magnetic Lasso tool (Photoshop 7.0)



# Lens

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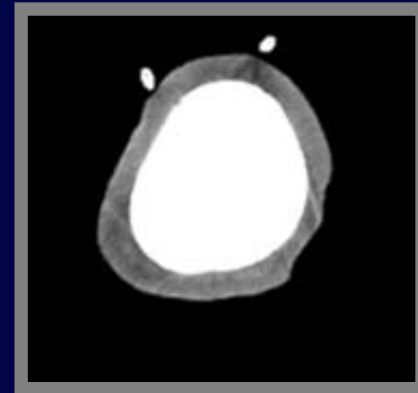
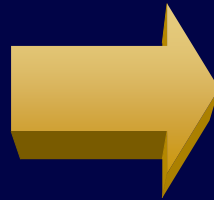
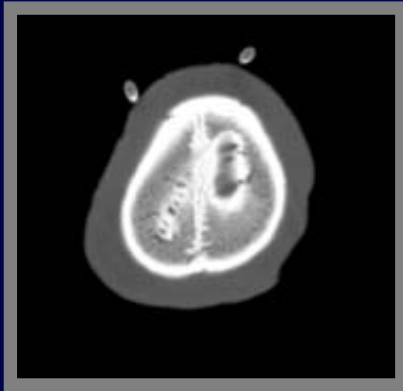


Photoshop 7.0

IDL 5.6

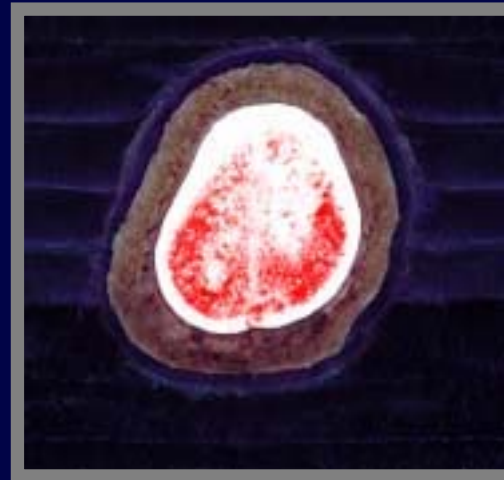
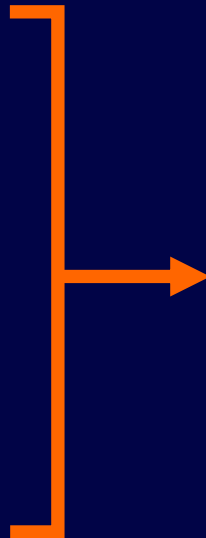
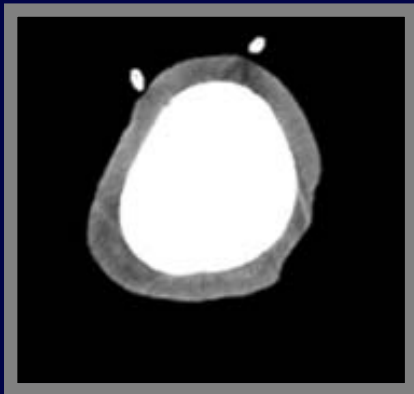
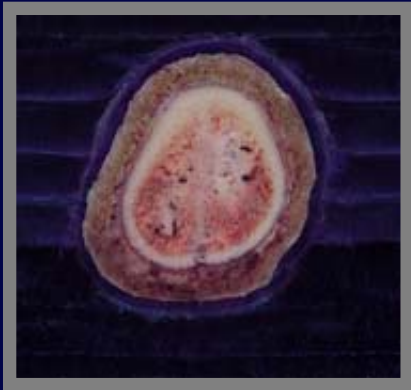
# RBM

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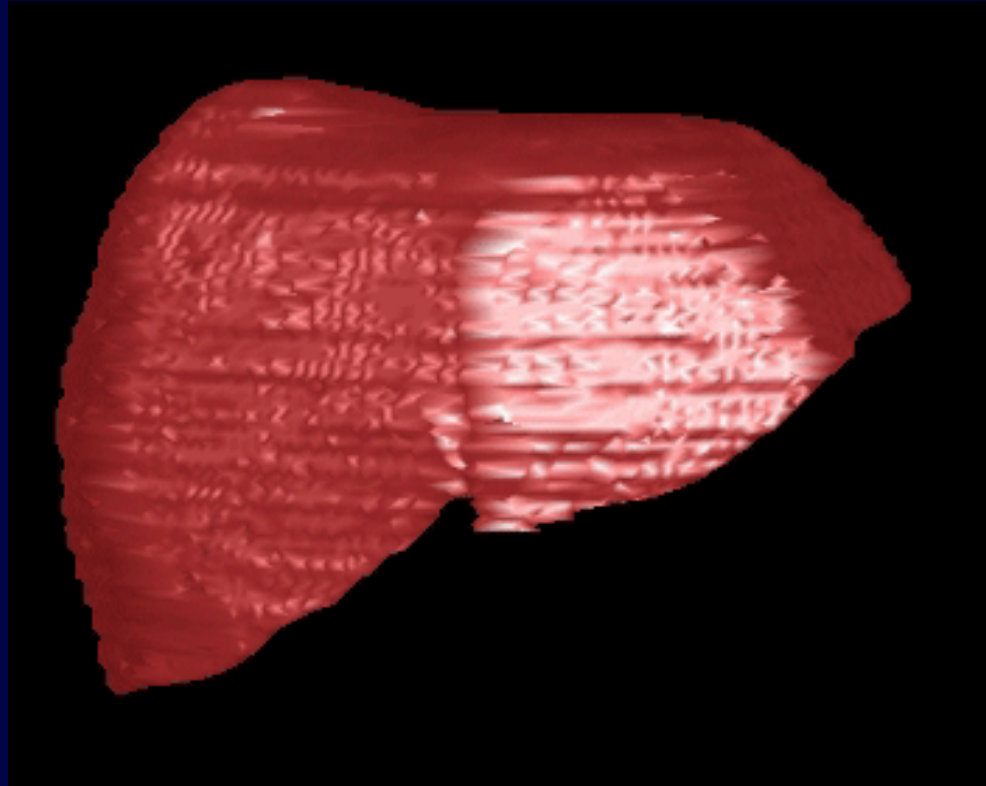
# RBM

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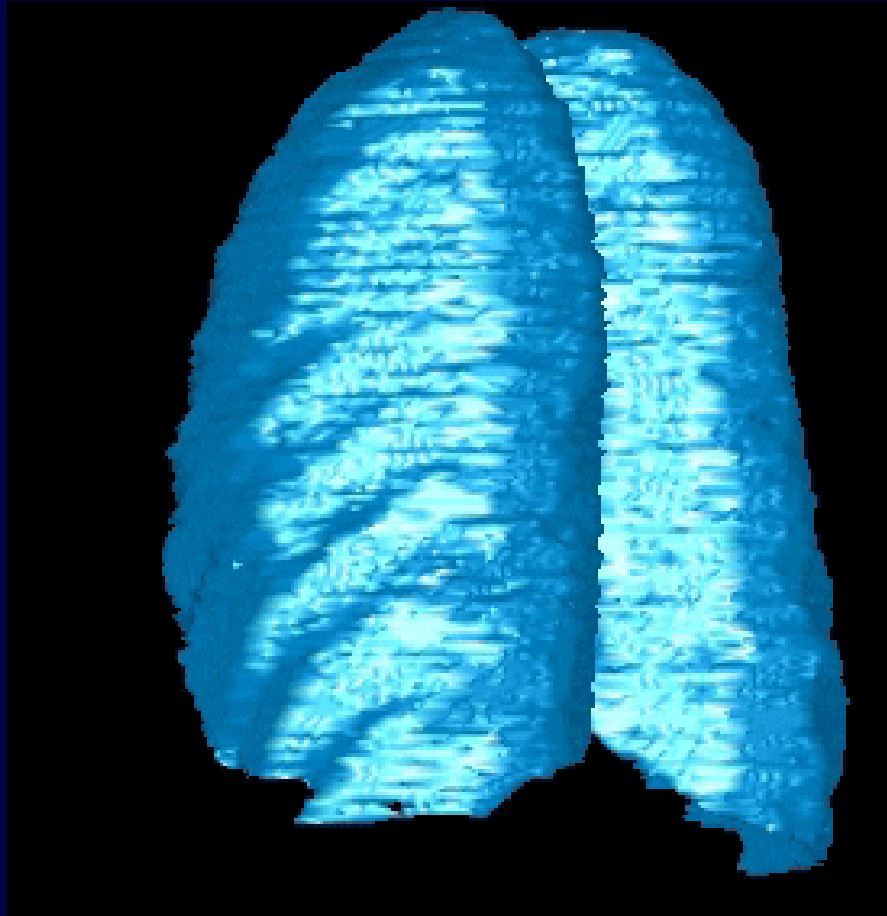
# Liver

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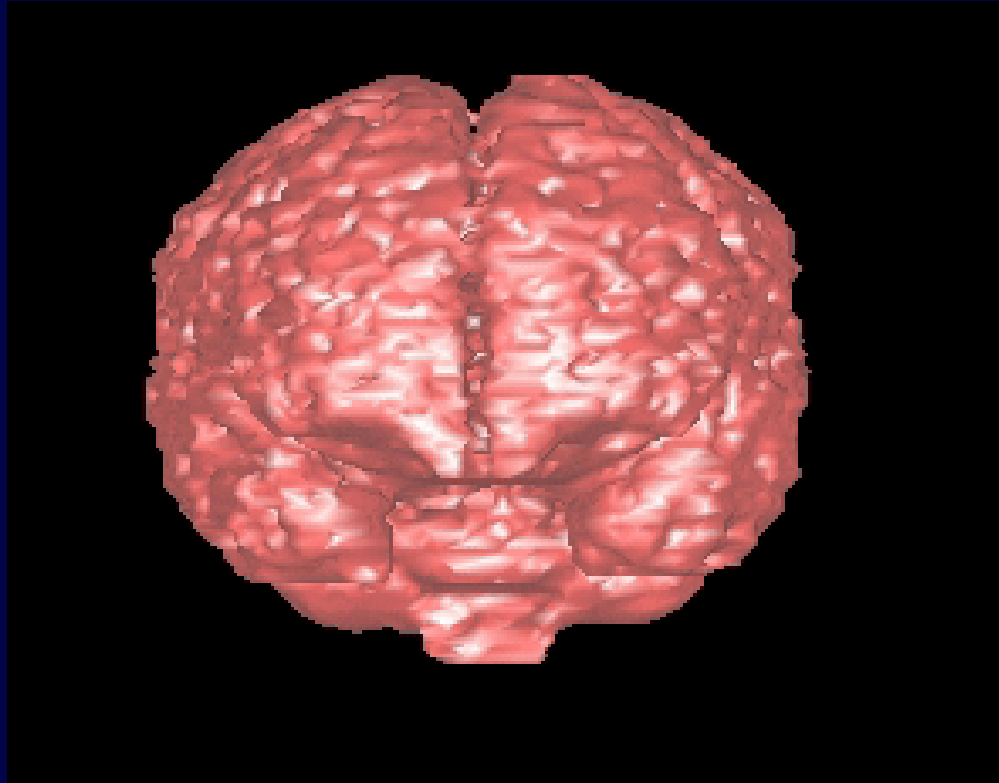
# Lung

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# Brain

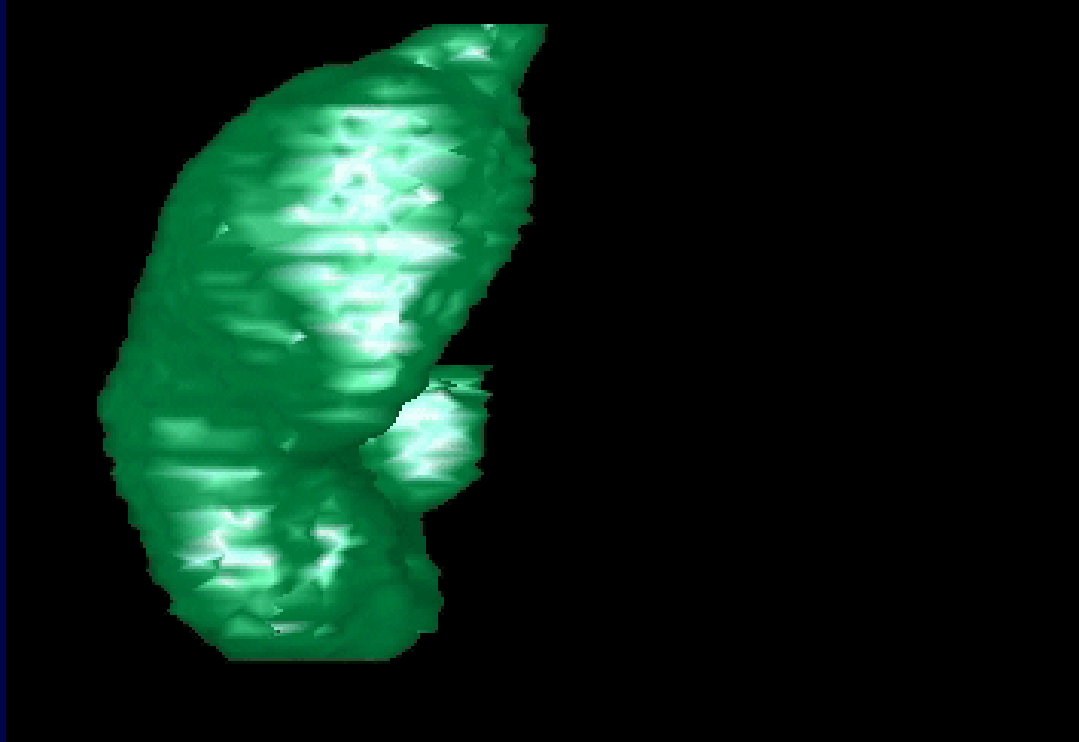
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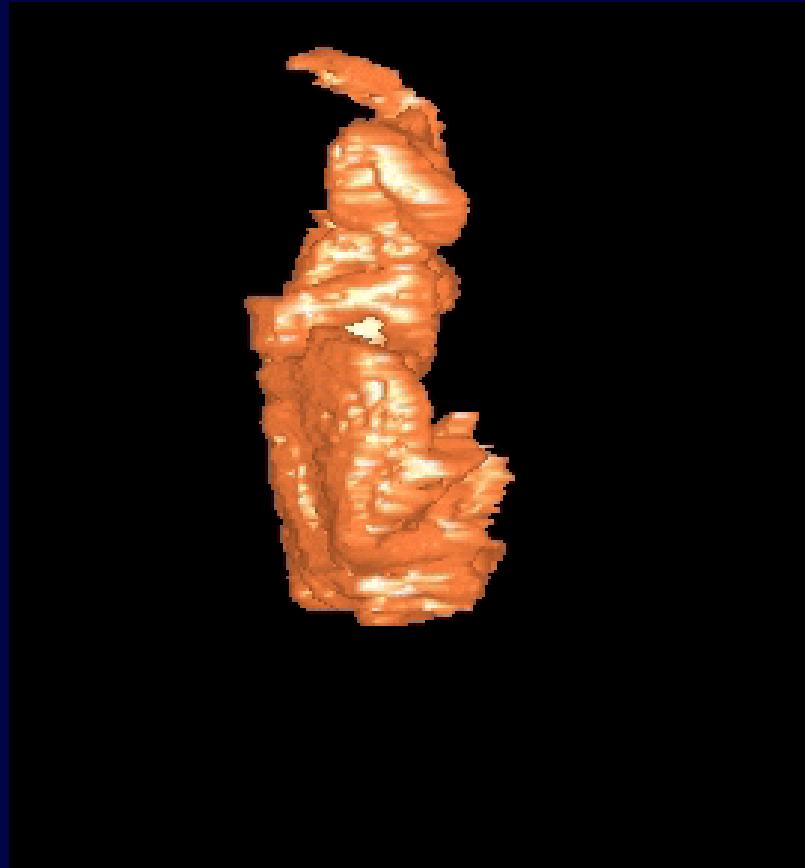
# Stomach

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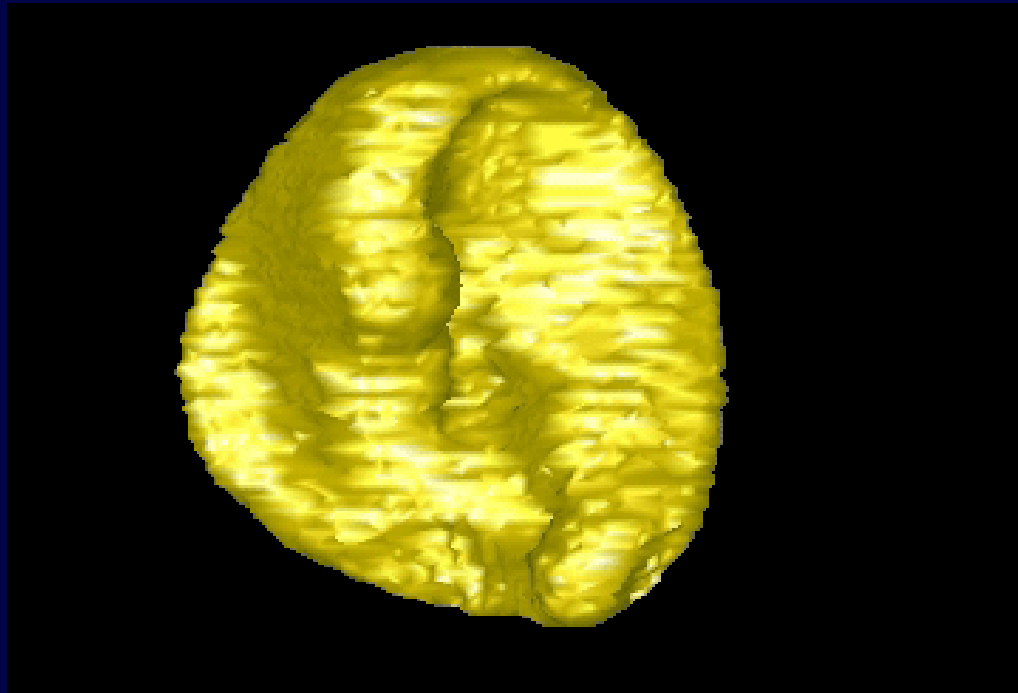
# Intestines

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# Spleen

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# Kidneys

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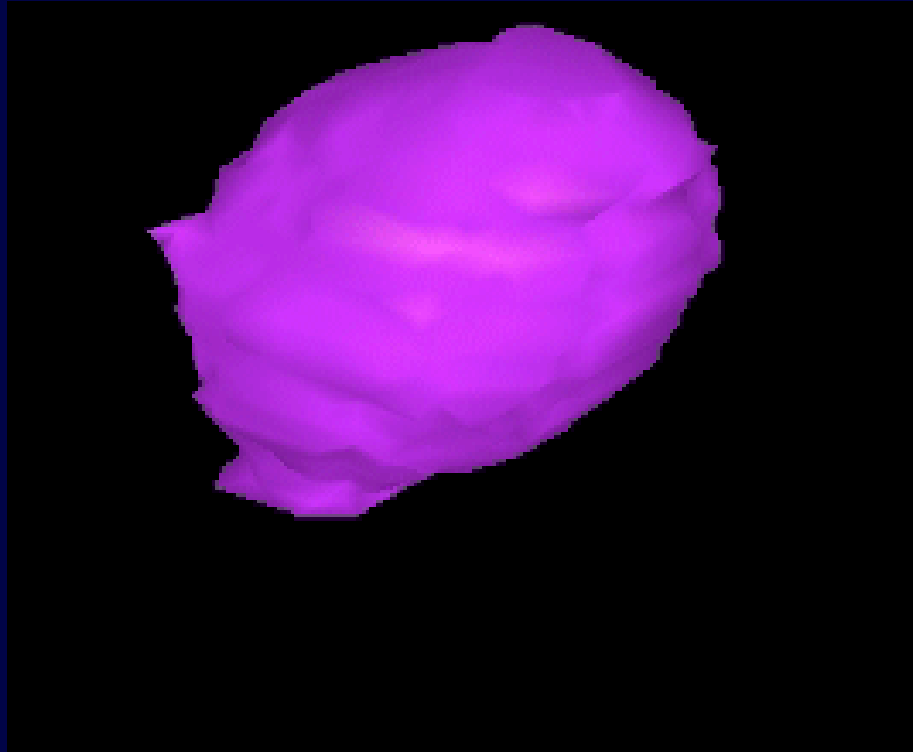
# Thyroid

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# Bladder

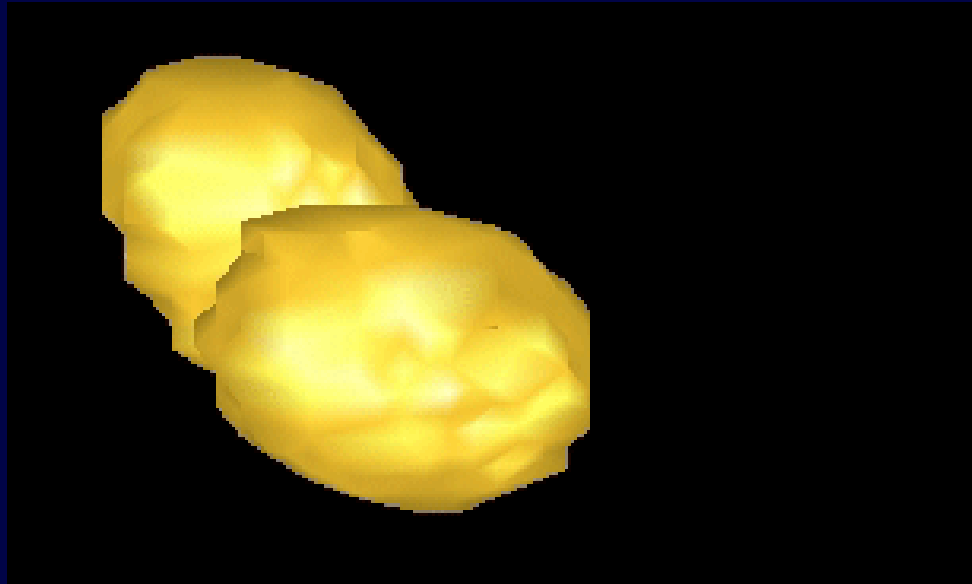
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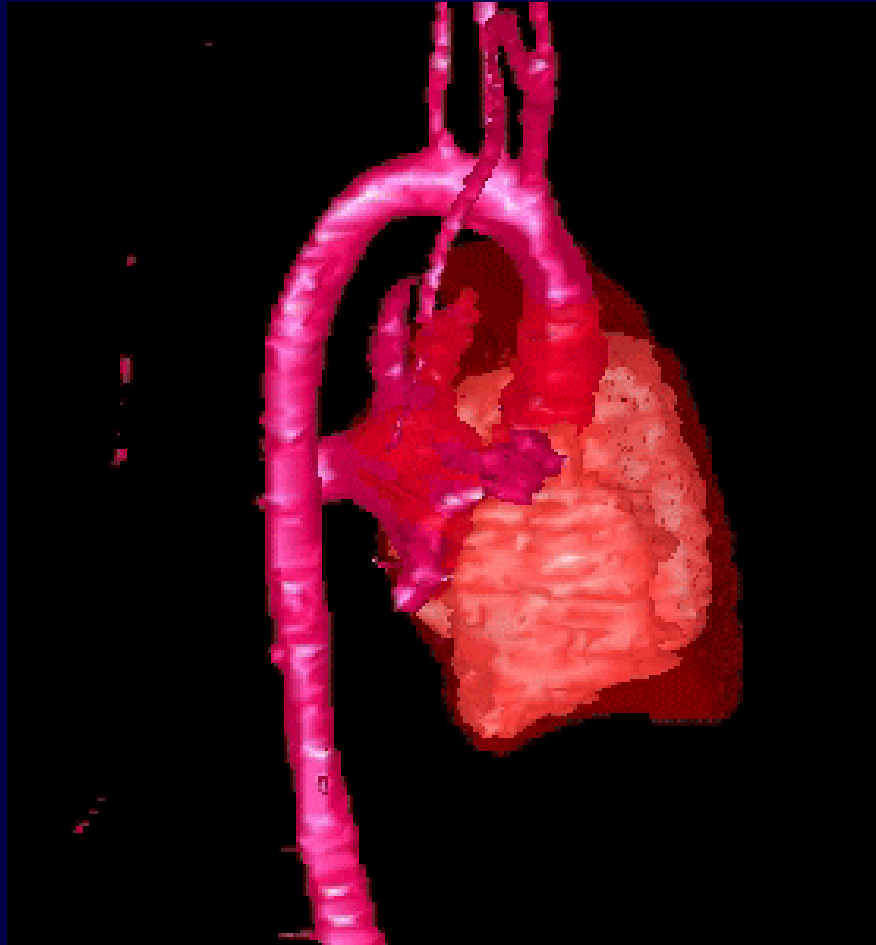
# Gonads

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# Heart Wall

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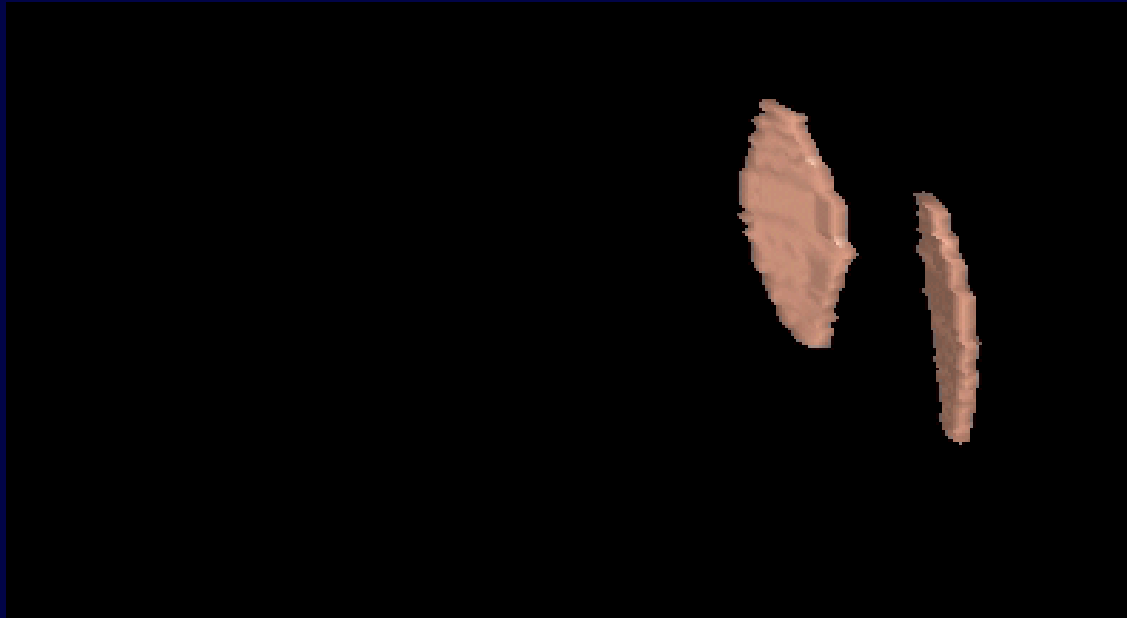
# Oral Mucosa

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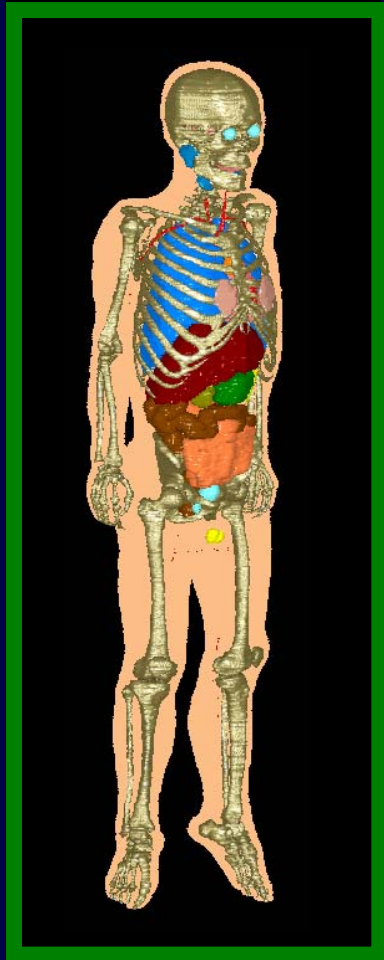


# Breast – Defined

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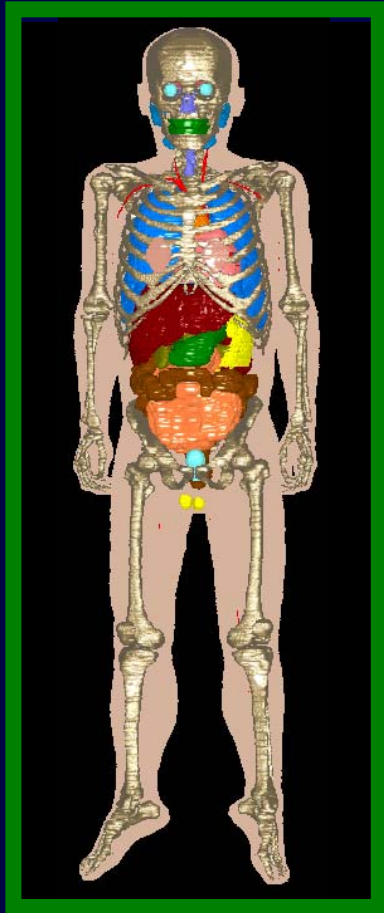
# Reconstructed Model



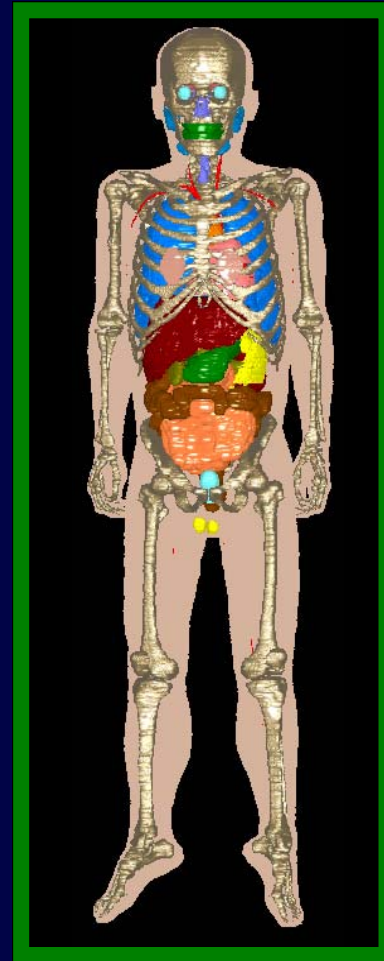
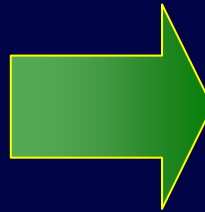
164 cm, 57.6 kg (↑)

Organ	Mass (g)	Organ	Mass (g)
Thyroid	18.8	Bladder	39.2
Lens	0.9	Thymus	28.7
Prostate	13.0	Muscle	19934.3
Salivary glands	75.8	Pancreas	108.5
Adrenal	8.5	Gonads	24.3
Oesophagus	34.0	Small intestine	253.1
Spleen	980.4	Colon	352.2
Stomach	164.8	Eyes	19.2
Lung	1476.9	Kidney	384.2
Red bone marrow	929.9	Extrathoracic tissue	63.0
Bone	7293.7	Gall bladder	104.4
Skin	3656.9	Heart wall	513.1
Brain	1701.6	Oral mucosa	19.1
Liver	1931.3	Blood	220.3

# Adjustment – Height



164 cm  
(2 mm)



171 cm  
(2.0854 mm)



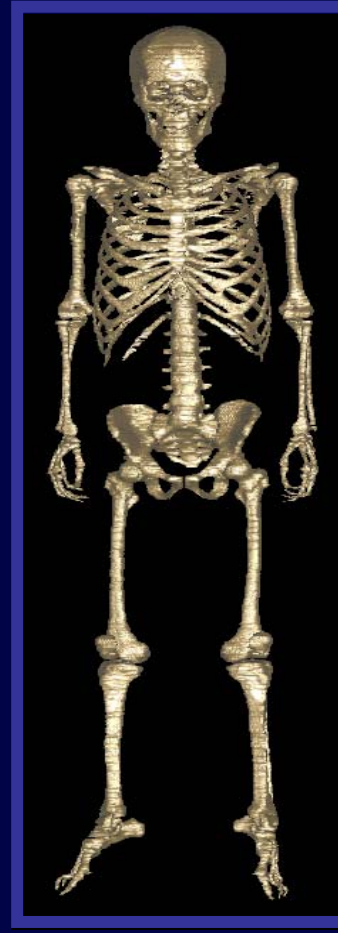
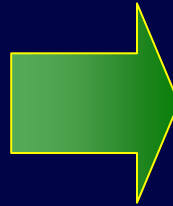
# Adjustment – Bone Mass

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8.6 kg

(1.875 mm x 1.875 mm)



9.6 kg

(1.981 mm x 1.981 mm)

# Adjustment – Organs and Tissues

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## ■ Reference

- ◆ Individual organs adjusted to the Reference Korean data
- ◆ Reference Asian data used for prostate, (urinary) bladder, adrenals, colon, small intestine

## ■ Larger Organs

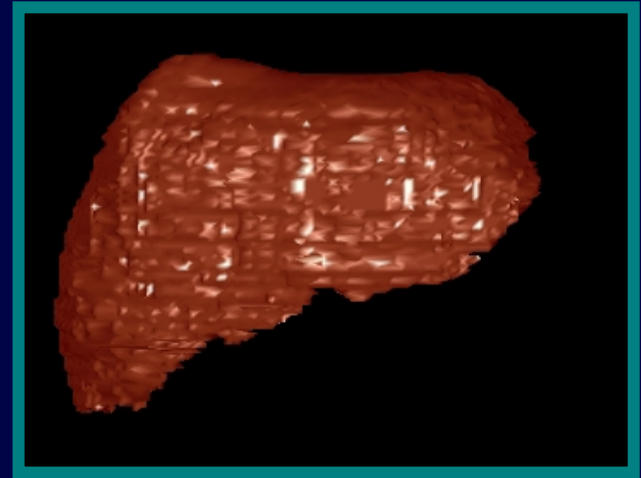
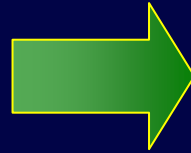
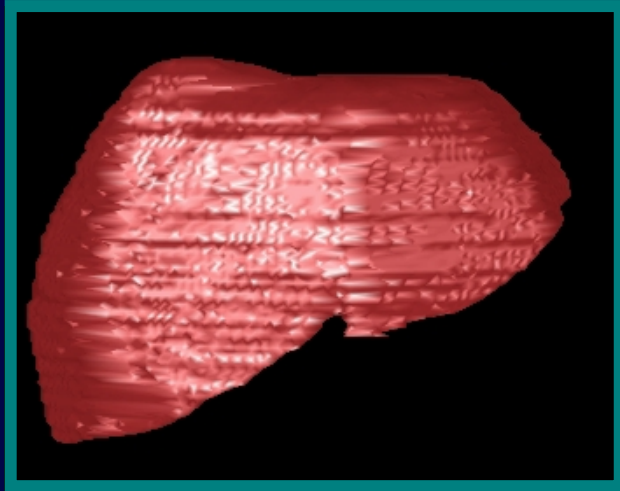
- ◆ Adjusted by erosion (Inner Grow, Photoshop 7.0)
- ◆ Eroded region filled with adipose tissue

## ■ Smaller Organs

- ◆ Adjusted by dilation (Outer Grow, Photoshop 7.0)

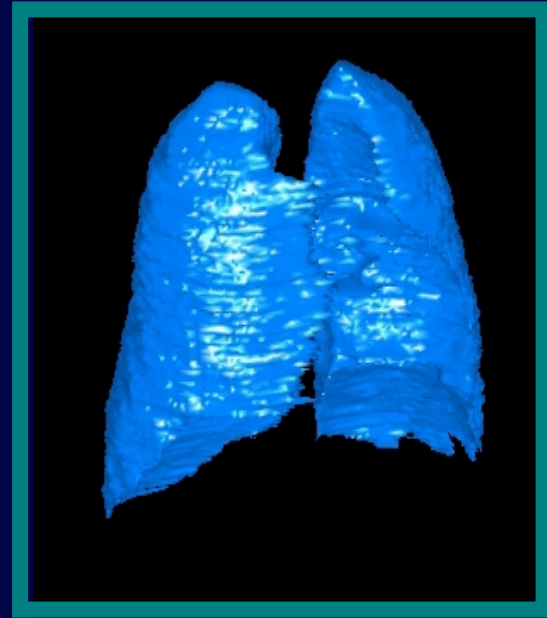
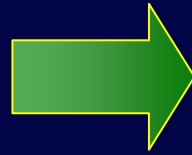
# Adjustment – Liver

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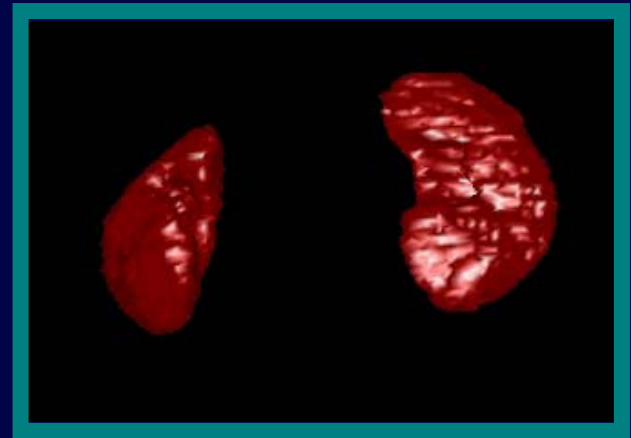
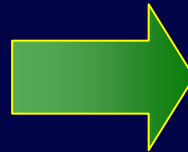
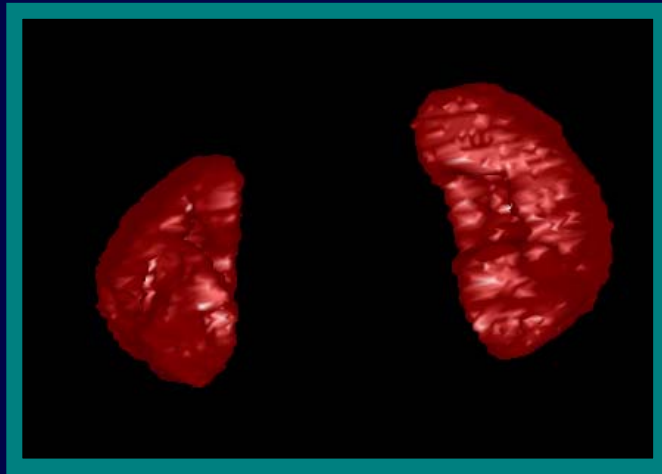
# Lung

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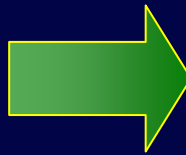
# Kidneys

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# Spleen – Problem!

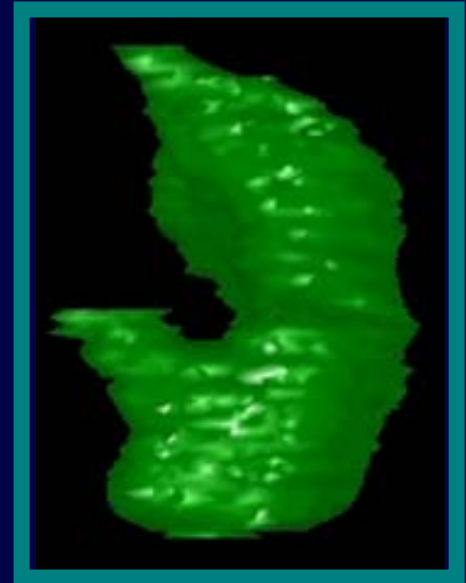
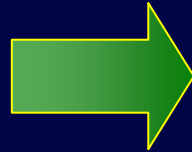
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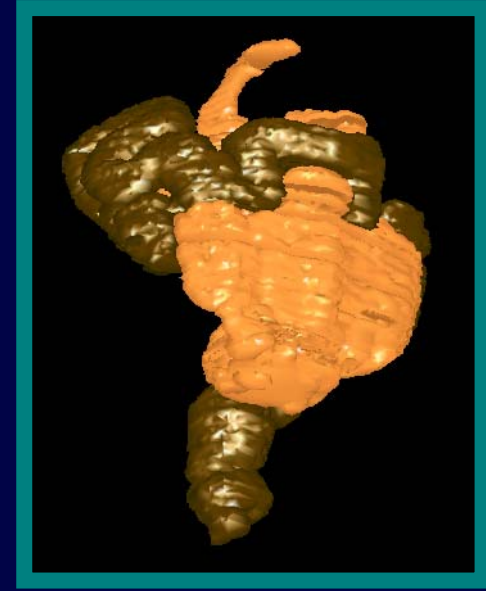
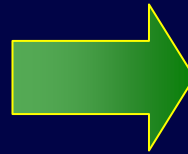
# Stomach

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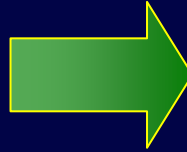
# Intestines

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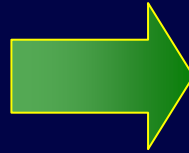
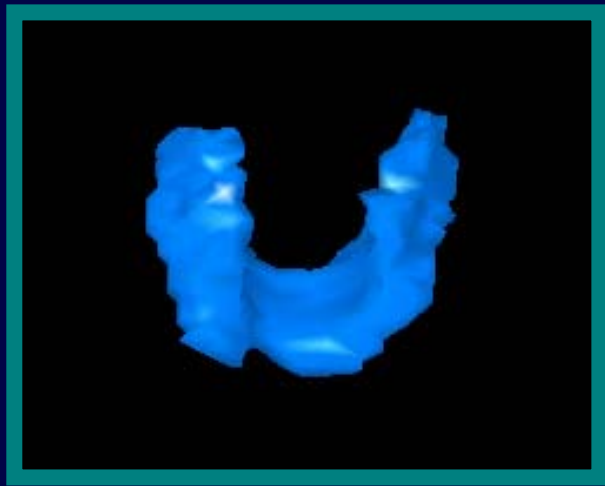
# Bladder

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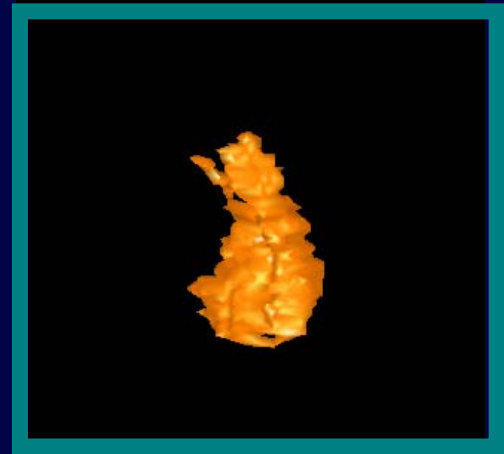
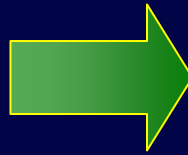
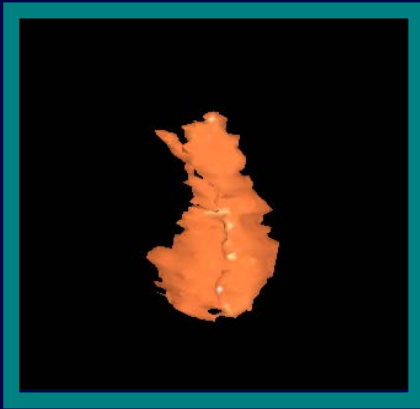
# Thyroid

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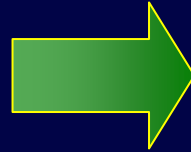
# Thymus

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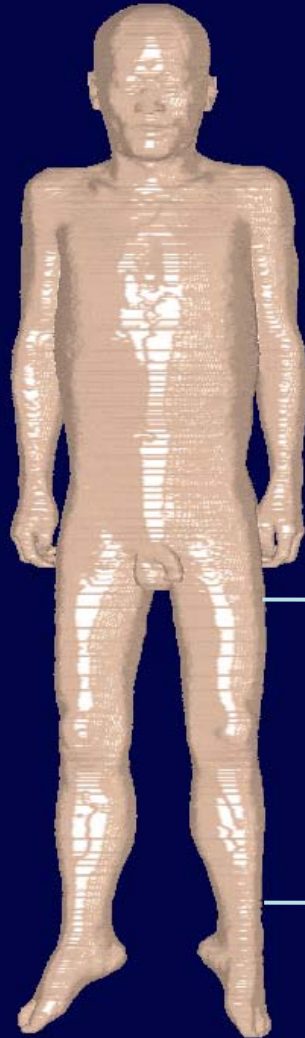
# Adrenals

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# Weight Tuning

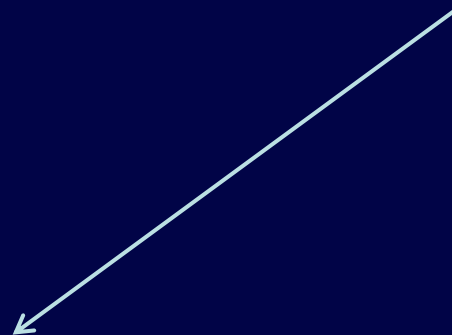
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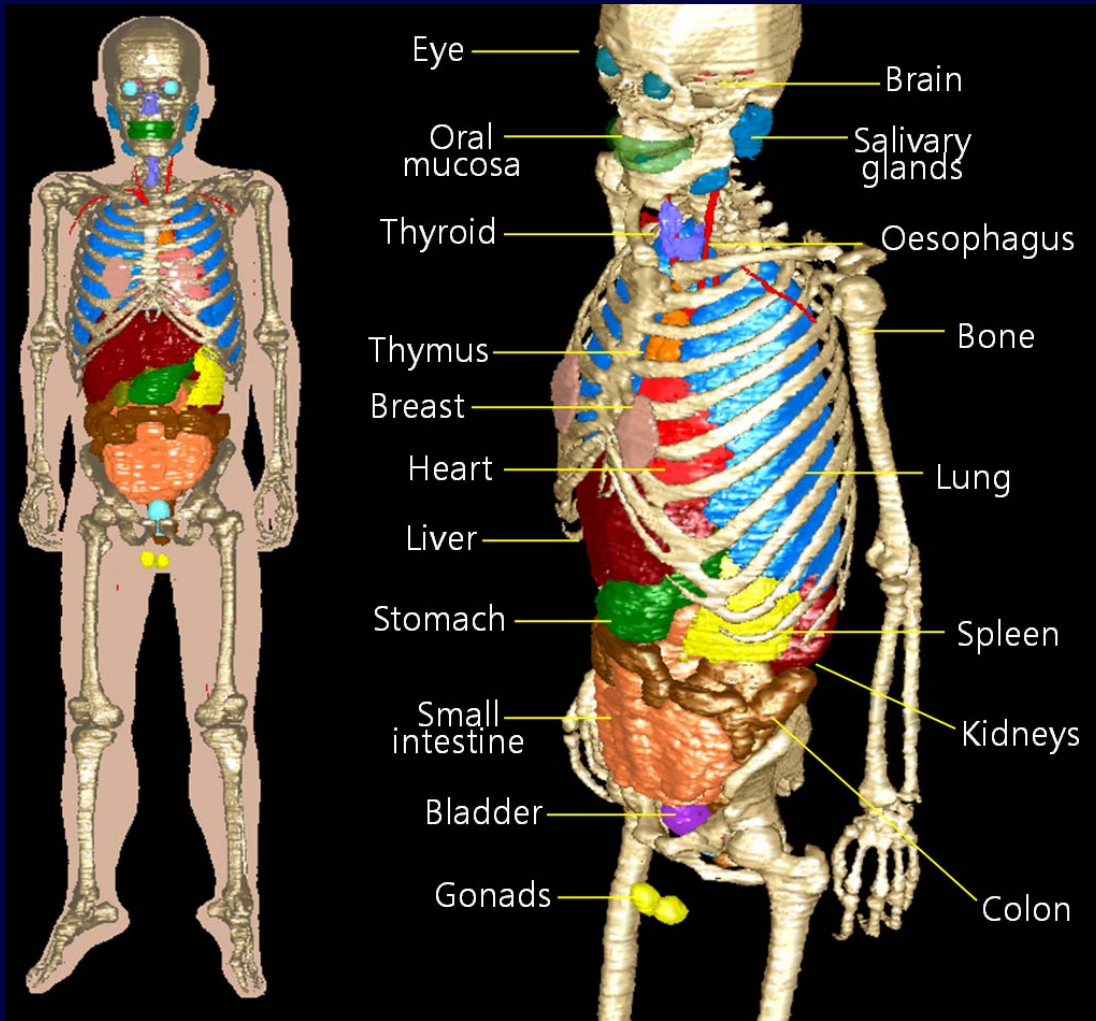
67.8 kg

➤ 0.2 kg added

Final weight: 68 kg



# HDRK-Man



171 cm, 68 kg

Voxel resolution:

$1.981 \times 1.981 \times 2.0854 \text{ mm}^3$

Voxel array:  $247 \times 141 \times 850$   
(29,602,950개)

➤X : 489.307 mm

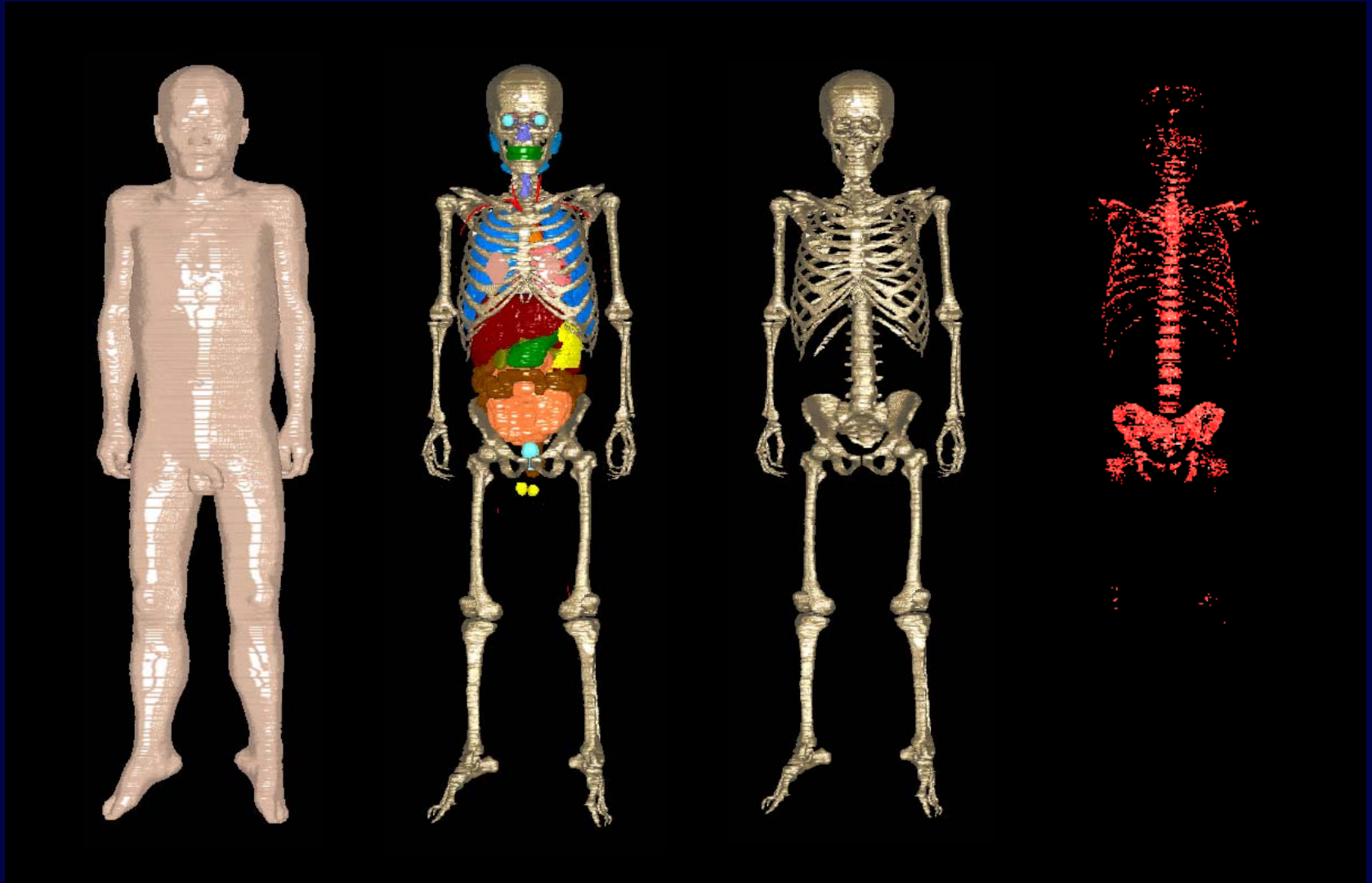
➤Y : 279.321 mm

➤Z : 1772.59 mm

30 organs segmented



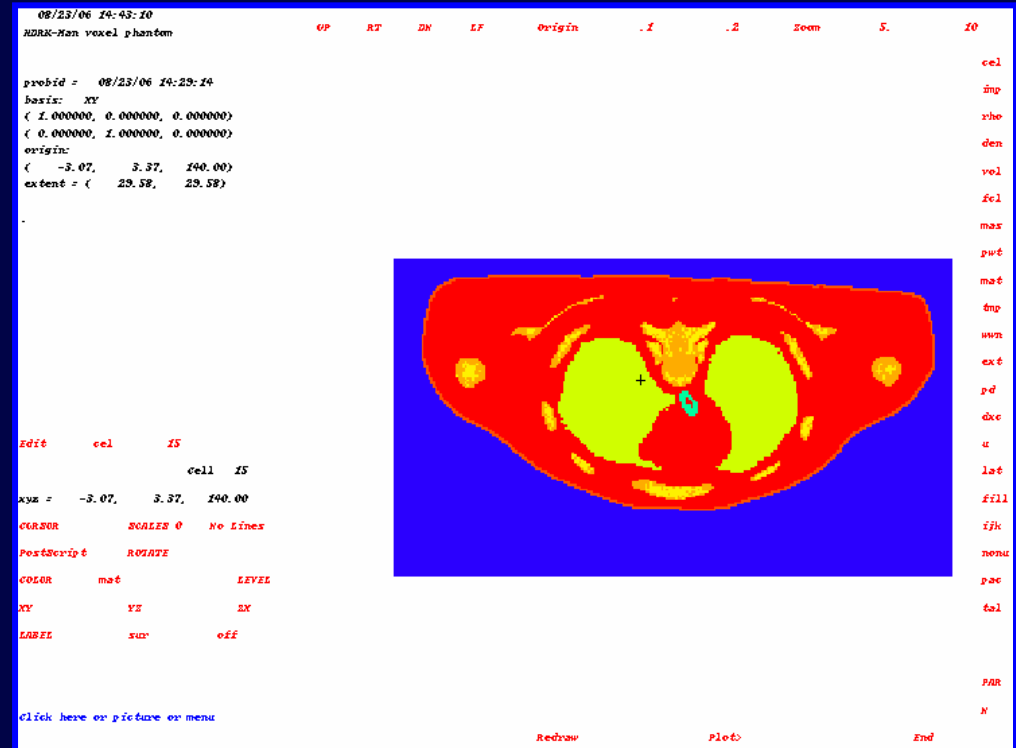
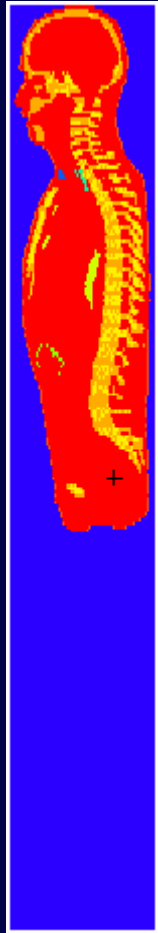
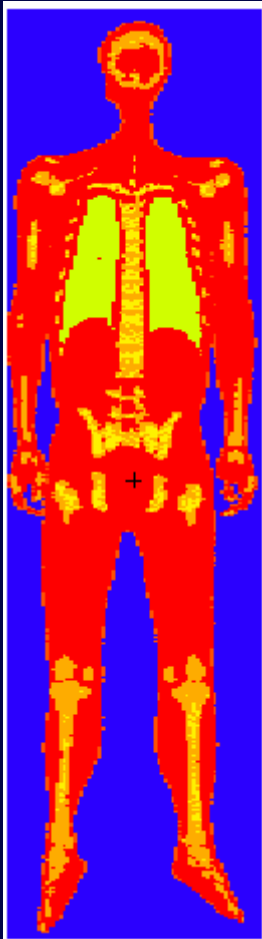
# HDRK-Man (Continued)



# HDRK-Man Organ Masses

Organ	Mass (g)			Organ	Mass (g)		
	HDRK-Man	Reference Korean	Difference		HDRK-Man	Reference Korean	Difference
Bone	9607	9649	-0.4%	Small intestine	602	590 <sup>a</sup>	2.0%
Liver	1474	1438	2.5%	Oesophagus	40	40	0.0%
Lung	1156	1123	2.9%	Adrenals	14	14 <sup>a</sup>	0.0%
Brain	1620	1522	6.4%	Skin	4260	2400	77.5%
Kidneys	359	338	6.2%	Extrathoracic region	73	-	-
Spleen	177	170	4.1%	Thyroid	15	15	0.0%
Stomach	141	140	0.7%	Bone-marrow (red)	1068	1000	6.8%
Pancreas	126	130	-3.1%	Prostate	12	12 <sup>a</sup>	0.0%
Thymus	39	40	-2.5%	Blood	254	-	-
Gonads	28	29	-3.4%	Salivary glands	87	82	6.1%
Eyes	21	20	5.0%	Gall bladder	13	13	0.0%
Lens	0.51	0.4	27.5%	Oral mucosa	21	-	-
Muscle	23300	25000	-6.8%	Heart wall	391	380	2.9%
Bladder	42	40 <sup>a</sup>	5.0%	Breast	23.3	22	5.9%
Colon	343	330 <sup>a</sup>	3.9%	Adipose tissue	23400.2	11000	112.7%

# HDRK-Man in MCNPX



# Monte Carlo Dose Calculations

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## ■ Calculated Values

- ◆ Dose conversion coefficients (organ-averaged absorbed doses per unit air kerma free-in-air,  $D_T/K_a$ )
- ◆ Compared with the reported values from other models (KTMAN-2, Rex, VIP-Man)

## ■ Considered Geometries

- ◆ Antero-posterior (AP), postero-anterior (PA), left-lateral (LLAT), right-lateral (RLAT)
- ◆ 0.015, 0.03, 0.04, 0.05, 0.08, 0.2, 0.4, 0.6, 0.8, 2, 8, 10 MeV (12 photon energies)

## ■ Dose Scoring

- ◆ F6 tally (MeV/g) assuming CPE
- ◆ Statistical error <5 % (except for 0.015 MeV)

# Percent Dose Deviation

## ■ Definition

$$\delta = \frac{D_M - D_{HDRK-Man}}{D_{HDRK-Man}} \times 100\%$$

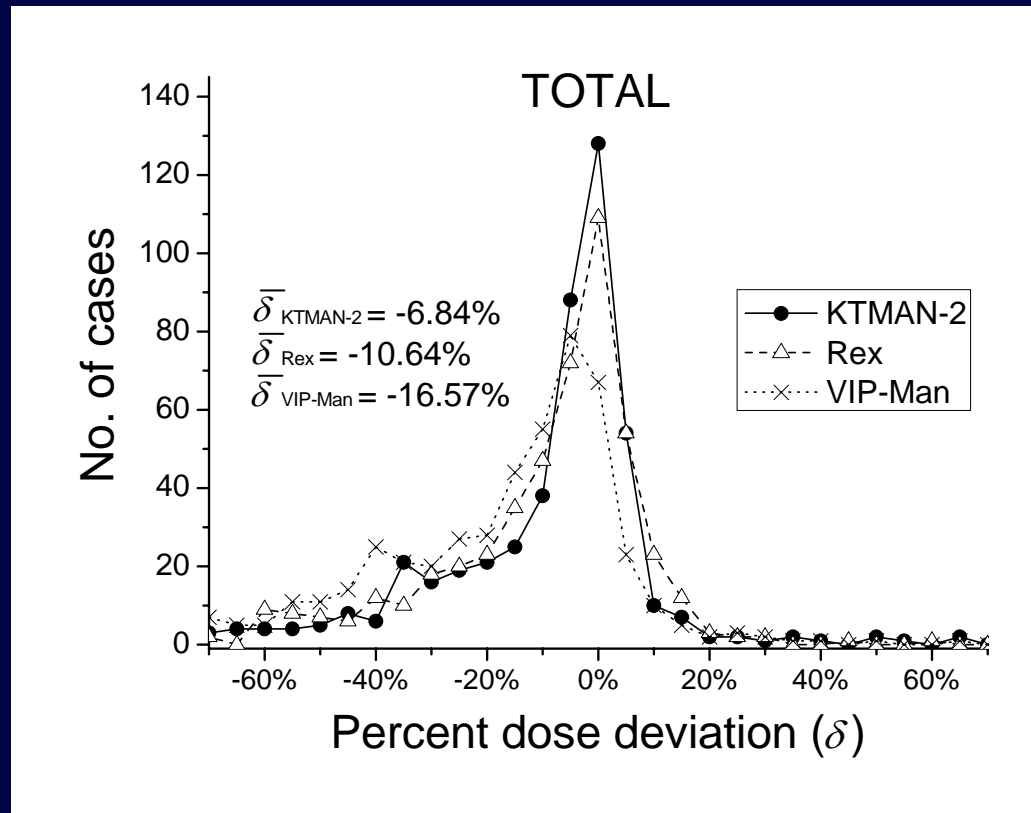
- ◆ It shows how much the dose conversion coefficient calculated by the voxel model M deviates from the value which calculated by HDRK-Man.

- + value:  $D_M > D_{HDRK-Man}$

- - value:  $D_M < D_{HDRK-Man}$

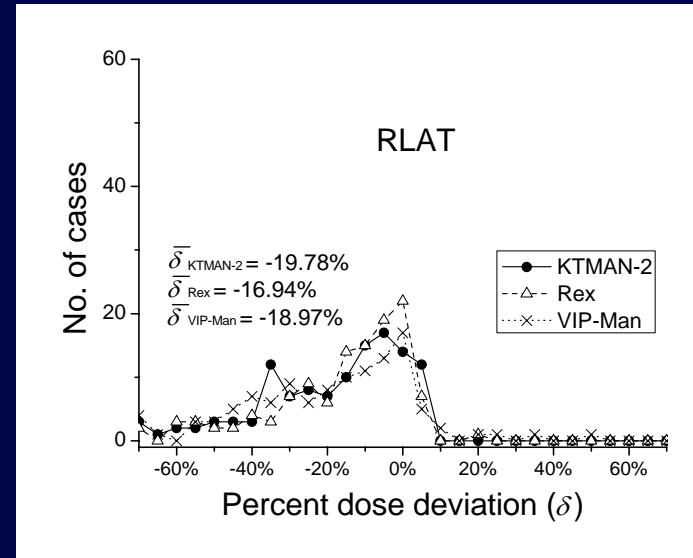
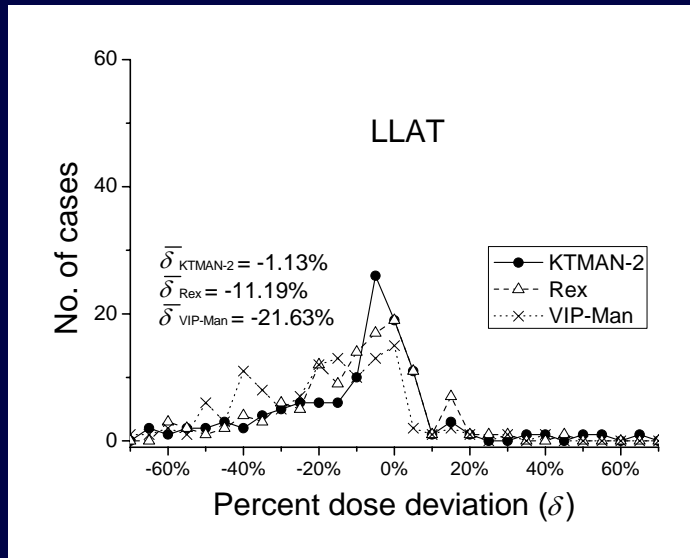
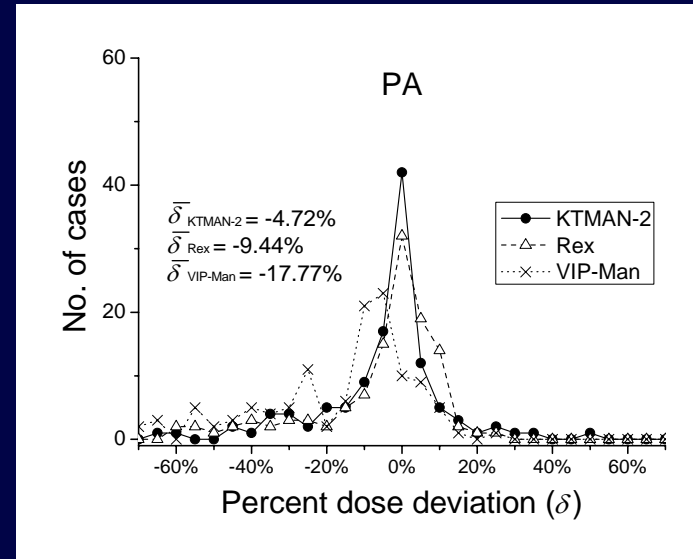
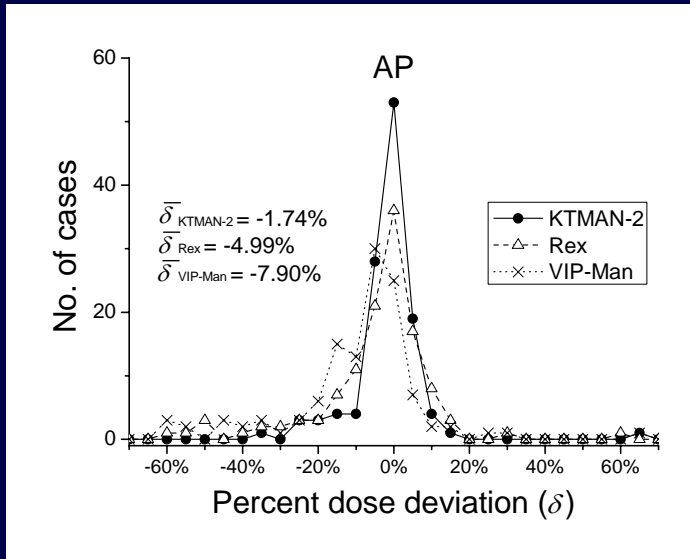
# Organ Dose Comparison

$$\delta = \frac{D_M - D_{HDK-Man}}{D_{HDK-Man}} \times 100\%$$



Considered: 4 irradiation geometries, 11 photon energies (0.03 – 10 MeV), 11 major organs , total 484 cases

# Organ Dose Comparison (Continued)



# Summary

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## ■ HDRK-Man

- ◆ Using high-resolution color photographic slice images
- ◆ Body height, weight, skeleton mass, organ dimensions adjusted to the Reference Korean data
- ◆ HDRK-Man adequately represents the average Korean workers

## ■ Medical Applications

- ◆ More precise model is needed
- ◆ Unadjusted model can be used instead

## ■ Higher voxel resolution

- ◆ Voxel resolution can be increased by factor of 10 for any part of the model
- ◆ Example
  - Eye: 0.1981 mm x 0.1981 mm x 0.20854 mm
  - Remainder: 1.981 mm x 1.981 mm x 2.0854 mm



Thank you ...