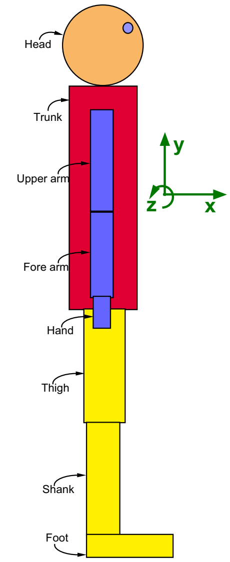
4.5 Lab: Human body segments mass properties



The figure to the right shows a ***human body*** that is divided into ***body segments***. The following words describe various directions on the human body.

Word		Meaning
superior	Up:	Towards your head
inferior	Down:	Towards your toes
anterior	Front:	Towards your chest
posterior	Back:	Towards your back
medial	Inside:	Towards the middle vertical line of your body
lateral	Outside:	Away from the middle vertical line of your body
proximal	Inboard:	Toward the human's mass center
distal	Outboard:	Away from the human's mass center

Whole-body scaling

Complete the C++ program `HumanMassProperties.cpp` so that its input is a **female** human's total mass (in kilograms) and total height (in millimeters) and its output is the mass distribution properties of her body segments. Write the results to the file `HumanMassPropertiesResults.txt` in the following format (each column is described below). Verify the results for the standard female (mass 61.9 kg and total height 1735 mm) described in [13].[2]

```
Segment   Length (mm)  Mass (kg)    CM (mm)     Ixx (kg*mm^2) Iyy (kg*mm^2) Izz (kg*mm^2)
Head      2.0020E+002  4.1349E+000  1.1800E+002  1.8048E+004  1.6759E+004  2.1359E+004
Trunk     5.2930E+002  2.6351E+001  2.1971E+002  9.4088E+005  2.1587E+005  8.4839E+005
UpperArm  2.7510E+002  1.5784E+000  1.5829E+002  9.2321E+003  2.6166E+003  8.0753E+003
ForeArm   2.6430E+002  8.5422E-001  1.2049E+002  4.0649E+003  5.2725E+002  3.9412E+003
Hand      7.8000E+001  3.4664E-001  5.8297E+001  5.9464E+002  2.3668E+002  4.3469E+002
Thigh     3.6850E+002  9.1488E+000  1.3310E+002  1.6916E+005  3.2604E+004  1.6460E+005
Shank     4.3230E+002  2.9774E+000  1.9090E+002  4.0864E+004  4.8125E+003  3.9667E+004
Foot      2.2830E+002  7.9851E-001  9.1640E+001  8.0412E+002  3.7208E+003  3.2397E+003
```

Column	Description
Segment	Segment name (Head, Trunk, UpperArm, ForeArm, Hand, Thigh, Shank, or Foot)
Length	Segment length in millimeters (distance between anatomical landmarks)
Mass	Segment mass in kilograms
CM	Distance (in millimeters) between the origin's anatomical marker and the segment's mass center
Ixx	Segment's moment of inertia about its mass center for the x-direction (see figure above)
Iyy	Segment's moment of inertia about its mass center for the y-direction (see figure above)
Izz	Segment's moment of inertia about its mass center for the z-direction (see figure above)

Modify the following functions in `HumanMassProperties.cpp`.
For ***whole-body scaling***, set `subjectSegmentLengthInMM` = 0 (otherwise ***segment scaling*** is used).

```
bool  DoRequiredTasks( void );
bool  WriteScaledBodySegmentMassPropertiesToFile( bool subjectIsFemale,          const char *segmentName,
                                                  Real subjectTotalMassInKG,     Real subjectTotalHeightInMM,
                                                  Real subjectSegmentLengthInMM, FILE *resultsFile );
```

[2] "Adjustments to Zatsiorsky-Seluyanov's Segment Inertia Parameters," by Paulo de Leva, *Journal of Biomechanics*, Vol. 29, No. 9, 1996, pp. 1223-1230.

Segment scaling

Another way to scale mass and inertia properties of human body segments is with ***segment scaling***. This process starts by measuring the length of the relevant body segment using anatomical markers, e.g., as described in [13].

1. For a **male** human of mass 90 kg with a foot of length 279.4 mm (11 inches) from the pternion (posterior point of the heel) to acropodion (tip of the longest toe), determine the mass, $\overline{\text{cm}}$ (center of mass distance from the heel), radii of gyration, and moments of inertia for **x**, **y**, **z** as shown on the previous page.

Mass	1.233	kg
$\overline{\text{cm}}$	123.36	mm
k_{xx}	34.6	mm
k_{yy}	71.8	mm
k_{zz}	68.5	mm
I_{xx}	1480	kg mm^2
I_{yy}	6357	kg mm^2
I_{zz}	5778	kg mm^2

2. The statement "***segment scaling*** is more accurate than ***whole-body scaling***" is true:
Never/rarely/sometimes/usually/always.
Explain:
The accuracy of either segment or whole body scaling will depend greatly on the model that is being used. If the model is constructed and applied well, segment scaling will probably be more accurate since it takes more information from the specific person. However, it is also limited by the accuracy of the measurement of body segments, and with more measurement, there is also more room for error in that respect.

3. The accuracy of mass and inertia properties is **much less/less/equally/more/much more** important to analyses of low speeds activities (e.g., walking) than during high speed activities(e.g., throwing a 100 mph baseball).
Explain:
Since what we are looking at is F = ma, when a is small, a change in m will not have as significant an effect. When a is very large, a small change in m will have a much greater impact on force, so the effect will be more significant for high speed/acceleration activities.

4. Measure your total mass (in kilograms), total height (in millimeters), and your segment lengths as described in [13]. Use `HumanMassProperties.cpp` to do both ***whole-body scaling*** and ***segment scaling***. Report your results in the files `YourNameMassPropertiesWholeBodyScaling.txt` and `YourNameMassPropertiesSegmentScaling.txt` in the following format.

```
Segment   Length (mm)  Mass (kg)    CM (mm)     Ixx (kg*mm^2) Iyy (kg*mm^2) Izz (kg*mm^2)
Head
Trunk
UpperArm
ForeArm
Hand
Thigh
Shank
Foot
```

5. Compare the results for your **body segment lengths** from the two scaling methods.
My body segment with the largest percentage difference is my hand (53%).
My body segment with the smallest percentage difference is my trunk (0.42%).

6. The **mass** of each body segment reported by the two scaling methods is the same. **True**/**False**.

   Explain: The masses are scaled from the total body mass not from the size of the segments.

7. Provide a reasonable method for scaling the mass of each body segment by its segment length.

   Step Description of calculation

   1. Scale the mass of each segment as is currently done in relation to the entire body.
   2. Multiply by the segment length measured.
   3. Divide by the expected segment length. This gives a first estimate for the mass of the segment.
   4. Do 1-3 for all segments.
   5. Add all the masses together to get a total mass for the entire body
   6. Divide the measured total mass by the total mass from step 5.
   7. Multiply the ratio from step 6 by the mass found in step 3. This step ensures that all the masses add up to the total mass as they should.