

[https://gin.g-node.org/kcl\\_cdb/fetal\\_brain\\_mri\\_atlas](https://gin.g-node.org/kcl_cdb/fetal_brain_mri_atlas)

↳ It is Part of the Project

#### Key Contents of this Atlas:

- **3D MRI Templates:** High-quality, noise-free, average 3D MRI images of fetal brains constructed from hundreds of real scans. *→ pregnancy*
- **Gestational Timeline:** It covers a range of gestational ages (e.g., usually from 21 to 36+ weeks), showing how the brain grows over time.
- **Manual Segmentations (The most important part for you):** These images come with labels. Experts have already manually colored in (segmented) the different parts of the brain (cortex, white matter, ventricles, cerebellum, etc.) for every single pixel in 3D space.

Your professor is proposing a Domain Adaptation or Synthetic Data Generation pipeline. This atlas is the "Ground Truth" engine for that pipeline.

1. **The Problem:** You want to build an AI that automatically finds brain structures in **Ultrasound (US)** images. But you **don't have** Ultrasound images with labels (manual segmentations) to train it.
2. **The Resource (This URL):** You **do have** MRI images with perfect labels (this KCL Atlas).
3. **The Project Task (Generative AI):** You will build a GenAI model (like a GAN or Diffusion model) that takes an **MRI image** from this atlas and "translates" it into a **fake Ultrasound image**.
4. **The Trick:** Since the fake Ultrasound was generated directly from the MRI, **the labels from the MRI atlas still apply to the fake Ultrasound**.
5. **The Result:** You now have a dataset of **Synthetic Ultrasound Images + Perfect Labels**.

You can use this new dataset to train your final segmentation model.

↳ the goal is to create labeled dataset of US

#### What is the Human Connectome?

The "Connectome" is essentially the wiring diagram of the brain. Just as the "Genome" maps our DNA, the "Connectome" maps the functional and structural connections between different areas of the brain. It seeks to answer: How is Part A physically connected to Part B, and how strong is that connection?

- **Why it matters for you:** Fetal MRI is incredibly difficult because the baby moves, and the brain is tiny. The dHCP created groundbreaking algorithms to fix motion and produce clear, high-resolution images.

The atlas you are downloading is the "summary" or "average" of hundreds of these scans, creating a perfect, noise-free representation of fetal brain growth.

#### 1. The Big Picture: dHCP and the Human Connectome

- **Human Connectome:** Imagine a map of a city that shows not just the buildings, but every single road, highway, and fiber-optic cable connecting them. The **Human Connectome** is exactly that, but for the brain. It is a comprehensive map of the neural connections (structural wiring) and functional networks in the human brain.
- **dHCP (Developing Human Connectome Project):** Most brain maps focus on adults. The **dHCP** is a massive scientific initiative (led by King's College London, Imperial College, and Oxford) to create a 4-dimensional map of the brain as it grows. They scan fetuses and babies (from 20 to 44 weeks) to understand how this "wiring" develops before and after birth.
- **Why it matters to you:** The data you have is likely from this "gold standard" project. It is the cleanest, most detailed data available for fetal brains.

- **Standard MRI (Structural):** Shows anatomy. It looks like a black-and-white photograph of the tissue shape.
- **Diffusion MRI (dMRI):** Measures the movement of water molecules on a microscopic level.
- **What is Diffusion MRI (dMRI)?** Standard MRI (like T1 or T2) shows you the shape of the brain (anatomy). Diffusion MRI measures the microstructure by tracking the movement of water molecules.
  - In a glass of water, water moves randomly.
  - In the brain, water molecules bump into cell walls and nerve fibers. By measuring how water moves, we can reconstruct the direction of nerve fibers (white matter tracts).

**How it works:** Imagine a straw filled with water. The water molecules can easily move up and down the length of the straw, but they can't move sideways through the plastic walls. In the brain, nerve fibers (axons) act like these straws. By measuring the direction water moves, dMRI allows us to reconstruct the white matter tracts (the cables) of the brain.

**In this dataset:** The Price et al. (2019) paper describes how they took dMRI scans of many fetuses and averaged them together to create a "probabilistic atlas" of where these white matter cables are located at every week of pregnancy.

- "Separate R/L structures" means the atlas does not just label "The Hippocampus." It has two distinct labels: "Left Hippocampus" and "Right Hippocampus."

**ROI (Region of Interest):** This is a standard imaging term. Instead of looking at the whole brain at once, scientists divide it into specific zones to analyze them one by one. Each "zone" is an ROI.

- Example: "The Hippocampus" or "The Frontal Lobe" are ROIs.

## Structural

- **T2w (T2-weighted):** The most common MRI type for fetuses. Fluid (like the ventricles) looks bright white; brain tissue looks grey. **This is your primary input image for the AI model.**
- **T1w (T1-weighted):** The opposite contrast. Fluid looks dark. Fetal T1s are rare and harder to get, but useful for seeing myelination (fatty sheaths around nerves).

## Summary of Use-Case for your Project

For the project your professor suggested (MRI → Synthetic US):

1. You will take the **Structural (T2w)** images as your source.
2. You will use the **Parcellations** as the labels for that source.
3. You will likely ignore the Diffusion files for now, unless your professor specifically wants to synthesize Ultrasound images that visualize white matter tracts (which is very advanced and unlikely for a first step).

## D. Transformations

- **Affine Transformations:** These are small mathematical files (usually text files with a  $4 \times 4$  matrix). They tell the computer how to rotate, scale, or shear an image to make it line up perfectly with a "common space" or template.

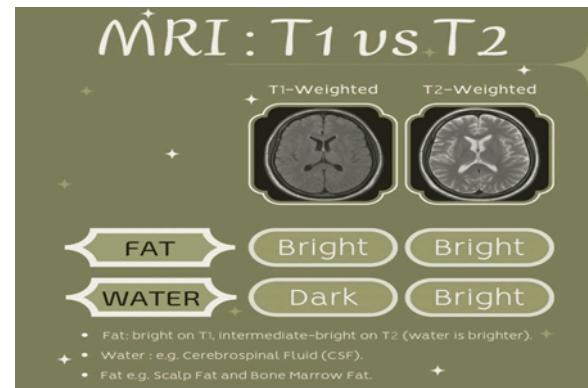
T1- and T2-weighted MRI images look different mainly because they are acquired with different timing parameters (TR and TE), which "select" whether T1 or T2 relaxation dominates the contrast between tissues. [mrimage +1](#)

## Key timing differences

- In T1-weighted sequences, the repetition time (TR) is short and the echo time (TE) is also short, so the image is most sensitive to how quickly longitudinal magnetization recovers (T1 relaxation). This makes fat (short T1) bright and fluids like CSF (long T1) dark. [radiologycafe +2](#)
- In T2-weighted sequences, both TR and TE are long, so longitudinal recovery is mostly complete and the image is dominated by transverse decay (T2 relaxation). Tissues with long T2 (e.g., water/edema/CSF) stay bright, while tissues with short T2 (e.g., fat and many solids) appear relatively darker. [abiscans +2](#)

## What is done differently during scanning

- The technologist selects different pulse sequences and adjusts TR and TE: short TR/TE for T1 weighting, long TR/TE for T2 weighting. These choices change when the signal is sampled relative to the RF pulses, so different parts of the relaxation curves are "seen" in each tissue. [directmedimaging +2](#)
- Apart from timing, other sequence parameters (flip angle, use of spin-echo vs gradient-echo, and sometimes fat or fluid suppression) can be chosen to further emphasize T1 or T2 effects, but the fundamental difference between T1 and T2 images is the use of short vs long TR/TE. [mrquestions +1](#)



T1- and T2-weighted MRI are used for different clinical questions because they highlight different tissues: as you said, T1 makes fat bright and fluid dark, while T2 makes fluid bright and most fat relatively darker. [pmc.ncbi.nlm.nih +1](#)

## T1-weighted MRI uses

T1-weighted images are mainly used to show normal anatomy and structural detail because fat, bone marrow, and white matter are bright and well delineated. They are also the main sequence for post-contrast scans, since gadolinium shortens T1 and makes enhancing tumors, inflamed tissue, or areas of breakdown of the blood-brain barrier appear bright against darker fluid. [abiscans +2](#)

## Common practical uses:

- Brain: anatomy, atrophy, mass effect, post-contrast tumor or infection evaluation. [mrimage +1](#)
- Spine and MSK: marrow pathology, fractures, and post-contrast assessment of tumors or infection. [sciencedirect +1](#)
- Whole body: pre- and post-contrast evaluation of organs (liver lesions, pituitary lesions, etc.). [pmc.ncbi.nlm.nih +1](#)

## T2-weighted MRI uses

T2-weighted images are highly sensitive to water, so any process that increases fluid (edema, inflammation, cysts, CSF) shows up bright, which makes them ideal for detecting pathology. They are widely used to identify areas of edema, demyelination, infarction, and fluid collections in many organs. [case +3](#)

## How clinicians choose between them

- When the question is "What is the anatomy and does this enhance with contrast?", T1 (especially with contrast) is emphasized. [mrimage +1](#)
- When the question is "Is there inflammation, edema, or abnormal fluid?", T2 (often with fluid-sensitive variants like FLAIR) is emphasized. [abiscans +1](#)

In practice, both T1 and T2 are almost always acquired together, and the radiologist compares them: one shows structure and enhancement (T1), the other shows fluid and edema (T2), giving a more complete picture of disease. [pmc.ncbi.nlm.nih +1](#)

- **FA (Fractional Anisotropy):** A map of "directionality."
  - Values range from 0 to 1.
  - 0 = Water moves randomly (like in a cup).
  - 1 = Water moves in a perfect line (like in a straw).
  - **Use:** Bright areas in an FA map show dense bundles of nerve fibers.
- **RD (Radial Diffusivity):** Measures water leaking out of the side of the nerve fiber. Used to track myelination (insulation) of the nerves.
- **Average DWI  $b=1000$  shell:** This is the raw-ish signal image taken when the magnetic gradient was set to a strength of  $b = 1000$ . It is a high-contrast image used to calculate the FA and MD.
- **ODF (Orientation Distribution Function):** A complex mathematical object. Instead of just saying "the fiber goes North," an ODF can describe "Two fibers cross here, one going North, one going East." This handles "crossing fibers" in the brain.
- **FA (Fractional Anisotropy):** A map of "directionality."
  - *Bright areas* = Water is moving in a straight line (dense nerve fibers).
  - *Dark areas* = Water is moving randomly (free fluid).
- **MD (Mean Diffusivity):** A map of "density." High values mean lots of space (like fluid); low values mean dense tissue.
- **RD (Radial Diffusivity):** Measures water moving *perpendicular* to the nerve fiber. Used to estimate how healthy the insulation (myelin) is around the nerve.
- **Average DWI  $b=1000$  shell:** This is the "raw" diffusion image taken with a specific magnetic strength ( $b = 1000$ ). It looks grainy but contains the raw data used to calculate FA and MD.
- **ODF (Orientation Distribution Function):** A complex mathematical object that describes the 3D direction of crossing fibers in a single pixel. (e.g., "70% of fibers go up-down, 30% go left-right").

<https://intergrowth21.com/research/brain-atlas-project>

↳ US dataset

This is the INTERGROWTH-21st Fetal Brain Ultrasound Atlas.

- **The Content:** It provides a 4D (3D + time) digital atlas of the fetal brain constructed entirely from 3D Ultrasound scans.
- **The Range:** It covers weeks 14 to 31 of gestation.
- **The Tech:** The researchers (Ana Namburete et al., *Nature* 2023) used AI to average thousands of real ultrasound scans into clean, sharp "canonical" templates for each week of pregnancy.

How you use this specific URL:

1. **Style Reference (The "Look"):** You want your AI to generate images that look like real ultrasounds. This atlas gives you the perfect, noise-reduced, standard definition of what a fetal brain ultrasound should look like at every week. You can use these images to train your model (e.g., in a CycleGAN or Diffusion model) to learn the "texture" and "style" of ultrasound physics (shadows, speckle noise, varying contrast).
2. **Validation:** Once your AI generates a "fake" ultrasound from an MRI, how do you know if it's anatomically correct? You can compare your generated image against this standard atlas to verify that the structures (like the ventricles or cerebellum) are in the right place and look realistic for that specific week of pregnancy.
3. **Cross-Modality Registration:** Since this atlas corresponds structurally to MRI, you can try to align (register) your MRI atlas (from dHCP) with this Ultrasound atlas to create a coarse "paired" dataset before you even start training your generative model.