

# HIPPOCAMPUS TRACING GUIDELINES

## 1. General Considerations

### 1.1 Anatomical

The hippocampus is located in the medial temporal lobe and is generally considered to be part of the so-called limbic system. The medial temporal lobe is formed by the amygdala, the enrolled and enfolded allocortical areas that form the hippocampal formation and the more superficial cortical areas of the parahippocampal gyrus which cover them (Van Hoesen 1995). Along its rostro-caudal axis the hippocampus may be divided into 3 sections.

- (1) A transversely oriented anterior segment (or head) which is dilated and shows elevations (digitationes hippocampi);
- (2) a middle segment, the "body", which is sagittally oriented and
- (3) a posterior segment (the tail), also oriented transversely and narrowing to disappear beneath the splenium (Duvernoy 1988).

The term hippocampal formation refers to a constellation of anatomically distinct structures, including the subiculum, the Ammon's horn (hippocampus proper) and the dentate gyrus. Since these structures are visually nearly indistinguishable on MR images they are sampled as a whole complex. This approach is supported by the fact that the mentioned structures, though of disparate anatomy, form a single functional unit (Duvernoy 1988, p.9). Accordingly, most of the efferent pathway of the hippocampus including the alveus, the fimbria and the fornix is excluded. Since these structures mainly contain myelinated axonal fibers they appear as white matter on the MRI scans and thus can be distinguished visually.

The anatomical landmarks and boundaries used for these guidelines follow basically the concise and extensive description given by H.M. Duvernoy in his Atlas of Applied Hippocampal Anatomy (1988). An additional neuroanatomical validation was provided by Prof. K. Zilles, Düsseldorf/Germany (personal communication) and Prof. G. Van Hoesen, Iowa City (1995 and personal communication).

## 1.2 Methodological

In contrast to most of the previously described volumetric MRI-based methods we aimed to sample the entire hippocampal formation according to its true anatomical definition. This task is complicated by the immense morphological complexity of the structure. This includes the fact that the shape of the cross-sectional area on the coronal plane changes considerably along the rostro-caudal axis. Additionally, separation of certain parts of the hippocampus from the adjacent brain structures on MR images is sometimes very difficult. This is particularly true with respect to the separation of the anterior part of the hippocampus from the amygdala and with respect to some posterior regions of the hippocampus (tail) which are adjacent to posterior parts of the thalamus (pulvinar). These difficulties led most of the previous investigators to either use arbitrary landmarks or to exclude certain parts of the structure from their measurements. In order to overcome these difficulties while tracing the hippocampal formation we use as much information as is available from the MRI scan.

Although the actual traces are done on the coronal plane of the continuous segmented image (stereo image) other modalities (T1 and T2) and planes (mostly the sagittal) are frequently used as a reference. In following the below described guidelines, an experienced tracer should be able to finish one hippocampal measurement in about 60-90 minutes. Accordingly, it takes about 2-3 hours to complete one individual brain.

## 2. Traces

Once BRAINS has been started in the user subdirectory (within the 10\_ACPC directory) the continuous segmented image (stereo image), as well as the realigned and fitted T1 and T2 images should be loaded. Tracing begins with the generation of the auxiliary guideline traces on the sagittal plane. Therefore the .roinames file should contain the names "r\_sag\_hippo" and "l\_sag\_hippo".

### 2.1 Auxiliary Guideline Traces (sagittal plane)

Care should be taken particularly with respect to the separation of the hippocampal head from the amygdala. This should be performed as accurately as possible. In general, the sagittal traces should be done on the T1 weighted images and trimmed on the stereo image. However, it should be taken into consideration that sometimes (particularly on the medial slices) the anterior border of the hippocampus is more visible on the stereo image. Place the cross-hairs in the center of the hippocampal formation on the coronal

view. Change to the sagittal and enhance (F3). Set the foreground region of interest to "r\_sag\_hippo" or "l\_sag\_hippo", respectively. The auxiliary traces should be sampled on every other sagittal slice.

Tracing starts on the medial slices. The starting slice can be identified by choosing the slice which (going from medial to lateral) first shows the cerebral peduncle separated from the upper pons (reference: Roberts et al., 1987 p. 75). At that level the head of the hippocampus appears as a small conical structure (**figure 1**) within the uncus/ambient gyrus just in front of the cerebral peduncle. At this level and in the following slices the hippocampal head is anteriorly bordered by the alveus (white matter tract) which is excluded from the measurement (**figure 2**). Once the anterior border of the hippocampus has been identified on the starting slice, the vertical cross-hairs should be placed just in front of it. This may facilitate the identification of the anterior border on the following slices, since the head of the hippocampus, in general, would not extend beyond this level on the more lateral slices.

Moving to the lateral side of the brain the full shape of the hippocampus becomes visible. The following borders can be identified:

**anterior border:** outlined by the alveus and the uncus which may be obliterated (**figure 2**)

**dorsal border:** CSF of the temporal horn of the lateral ventricle outlines the body (**figure 2**), whereas the pulvinar thalami serves as the boarder for the tail. On the medial slices the body is bordered by the fimbria which is excluded (**figure 3 and 4**).

**posterior border:** CSF of lateral ventricle (**figure 5**)

**ventral border:** white matter of the temporal lobe, the slice which shows the amygdala/hippocampal transition zone should be sampled in any case. At that slice the head of the hippocampus bends anteriorly and forms a little tip which points toward the frontal lobe (see **figure 2 and 3** and Duvernoy, 1988, p. 105). This is usually the fourth or fifth slice following the starting slice. The sagittal traces are checked and trimmed on the stereo image.

Figure 1

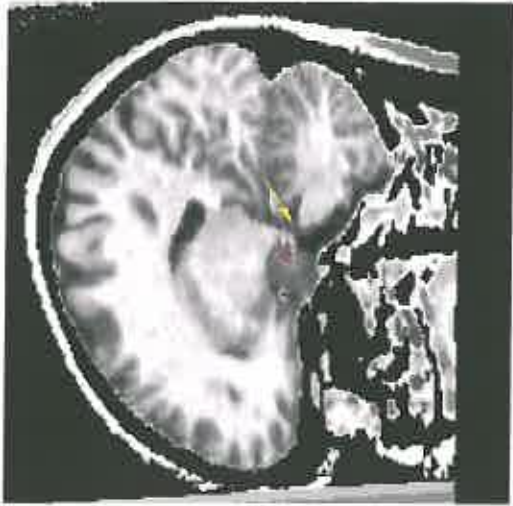


Figure 2

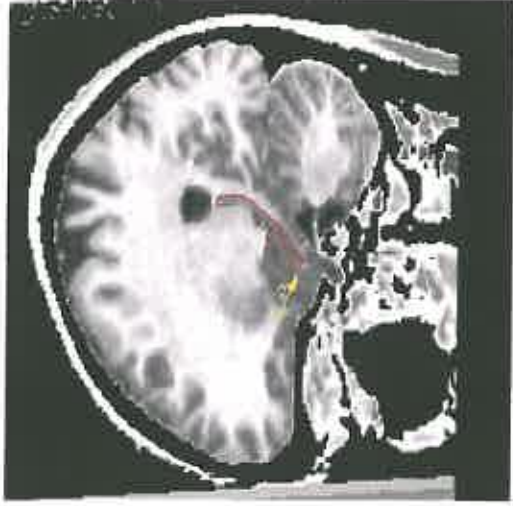


Figure 3



Figure 4

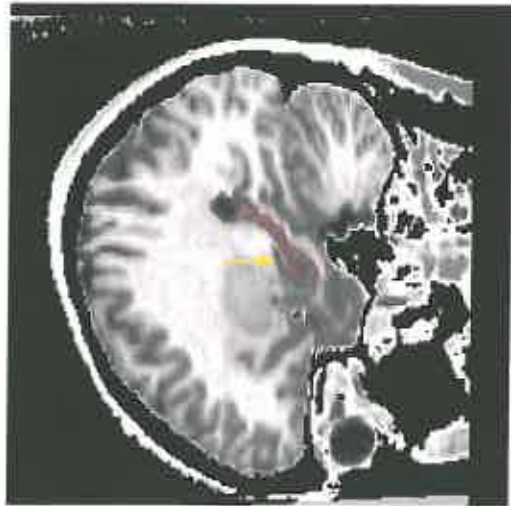
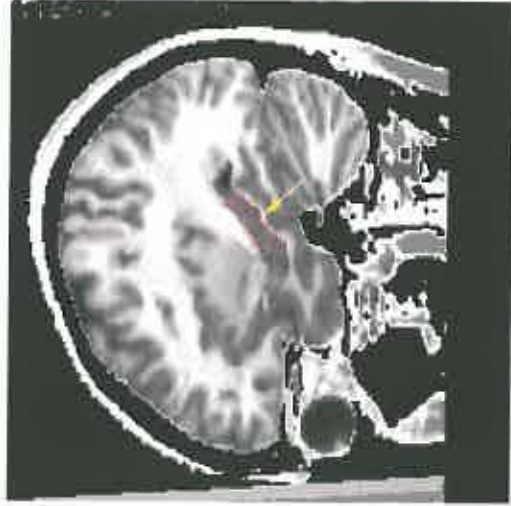


Figure 5



## 2.2 Coronal Traces

Place the cross-hairs anterior to the hippocampal head in the sagittal plane and switch to the coronal view. The coronal traces are the actual traces. They are performed on the stereo image using the F3 enhancement. Move backwards until the first yellow crosses telegraphed from the sagittal guideline traces appear.

### 2.2.1 Head

The tracing of the hippocampal head starts at the slice which for the first time shows more than 2 telegraphed crosses (defining an area). At that level it is usually very difficult, sometimes even impossible to differentiate the hippocampal head from the amygdala just above it on the basis of pixel intensity. Therefore, the tracer has to rely heavily on the information from the sagittal plane as provided by the telegraphed crosses. Sometimes however, the alveus may be identified and serve as a border between hippocampus and amygdala (white matter having higher signal intensity). If this is the case the alveus is excluded as previously. The head of the hippocampus appears as a transversely oriented oval or crescent-shaped structure (see figure 6 and Duvernoy, 1988, p. 54).

The following borders are used:

**lateral border:** Use the temporal horn of the lateral ventricle (the edge between grey matter and CSF is sometimes blurred on the stereo image (figure 7). Use the T1 and T2 weighted image as reference.

**dorsal border:** Follow the line defined by the telegraphed crosses, sometimes the alveus is visible (exclude), the uncal sulcus is usually obliterated on the most anterior slices. When it becomes visible the uncal recess serves as the dorsal border (figure 7 and 8).

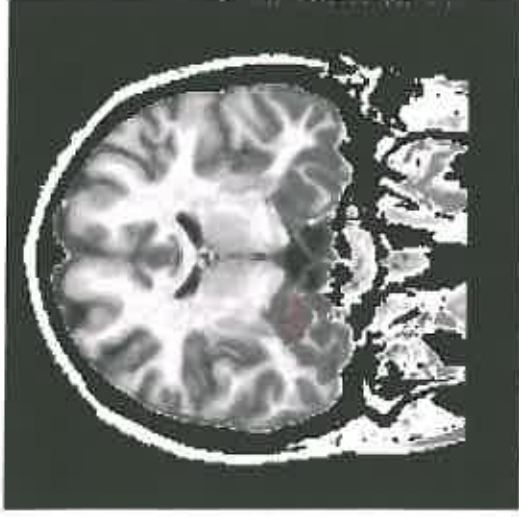
**medial border:** Again the telegraphed crosses provide an orientation on most anterior slices. Tracing includes parts of the ambient gyrus, and on some slices the endorhinal sulcus serves as a border.

**ventral border:** Laterally the white matter of the temporal lobe defines the border; medially the subiculum has to be cut off from the cortex of the parahippocampal gyrus. This is done by following the horizontal line which is defined by the subiculum/white matter border (figure 8).

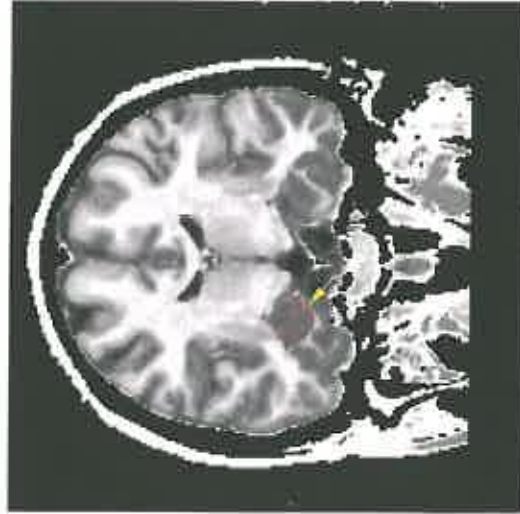
**Figure 6**



**Figure 7**



**Figure 8**



## 2.2.2 Body

The body of the hippocampus comes into view at about the level of the red nucleus.

The following borders are used:

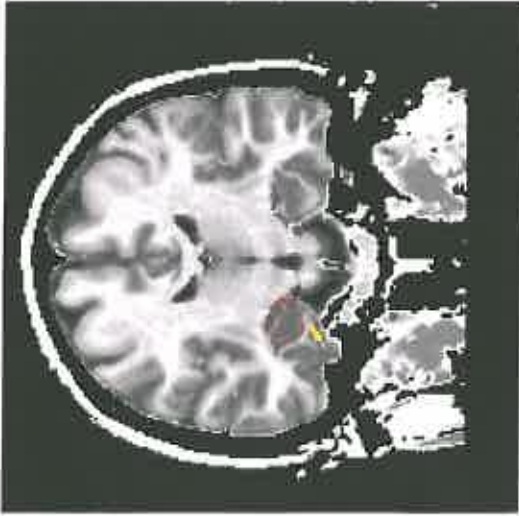
**lateral border:** temporal stem and inferior horn of the lateral ventricle are used (**figure 9**)

**dorsal border:** exclude alveus and fimbria, noting the CSF of the lateral ventricle (**figure 10**)

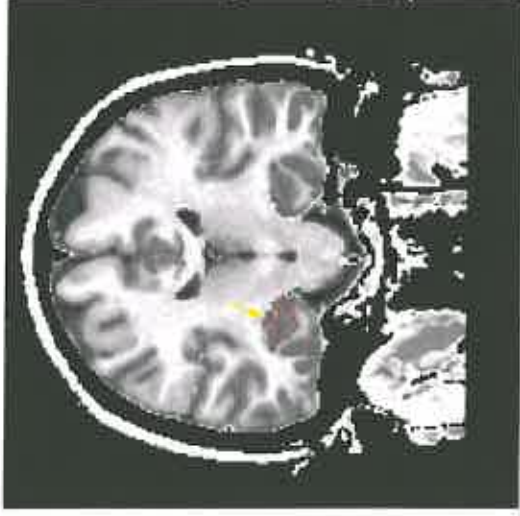
**medial border:** CSF of the ambient cistern and the crus cerebri serve as the border

**ventral border:** the white matter of the temporal lobe defines the inferior border. Exclude the parahippocampal gyrus as described above (**figure 9**).

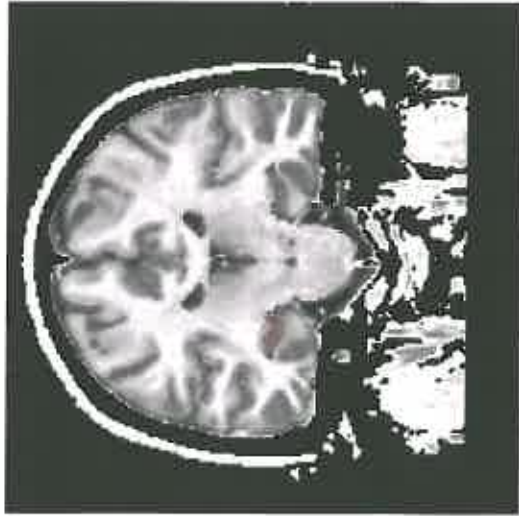
**Figure 9**



**Figure 10**



**Figure 11**





### 2.2.3 Tail

The tail of the hippocampus starts at about the level where the brainstem becomes separated from the midbrain (level of superior colliculus/ pineal gland, **figure 12**).

The following borders are used:

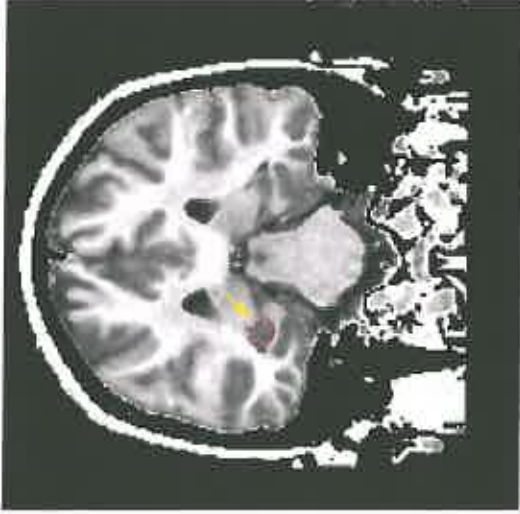
**lateral border:** Use the ascending crus of the fornix and the CSF of the atrium of the lateral ventricles (**figure 13**, blue arrow). It is usually difficult to differentiate the intraventricular part of the tail from ventricular CSF (**figure 14**), necessitating the use of the telegraphed crosses as a guideline.

**dorsal border:** This border is defined by the pulvinar of the thalamus (**figure 12**); separation of the hippocampal head may be very difficult due to partial voluming effects; therefore, the sagittal plane should be used as a reference. On the most caudal slice the dorsal border is marked by the lower border of the splenium of the corpus callosum (**figure 13**, yellow arrow). This part of the hippocampal tail is sometimes referred to as the subsplenial gyrus.

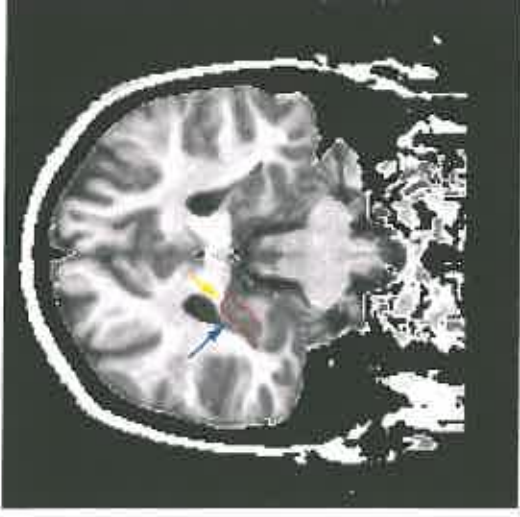
**medial border:** CSF of the quadrigeminal cystem, on the terminal slices the fasciola cinerea and the gyrus fasciolaris as well as the gyrus of Andreas Reizius are included (reference: Duvernoy 1988, p. 93)

**ventral border:** white matter of the temporal lobe (parahippocampal gyrus) is used

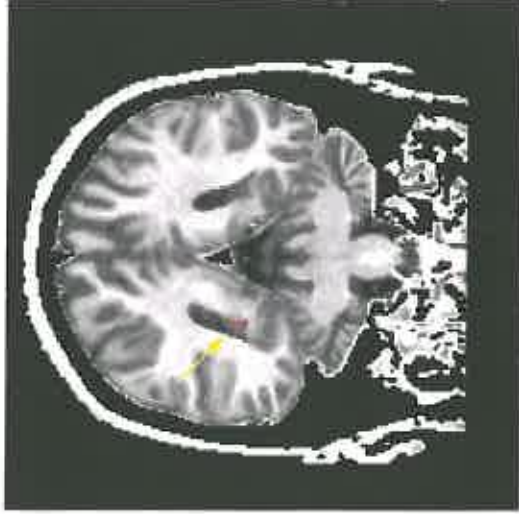
**Figure 12**



**Figure 13**



**Figure 14**



### **3. Final check and trimming**

Final check and trimming starts again on the most anterior slices using the F2 enhancement. All background traces should be turned off. Care should be taken particularly to the medial and lateral borders. Refer to T1 and T2 images in order to identify and exclude CSF which might have been included erroneously.

### **4. References**

- Duvernoy H (1988) *The Human Hippocampus. An Atlas of Applied Anatomy.* JFBergmann, Munich.
- Van Hoesen GW (1995) *Anatomy of the Medial Temporal Lobe. Magnetic Resonance Imaging* 13: 1047-1055.
- Roberts M, Hanaway J, Morest DK (1987) *Atlas of the Human Brain in Section.* 2.edition. Lea and Febiger, Philadelphia.

