**Image Classification using VGG19 (Transfer Learning) with Robust Evaluation**

**Objective:**  
Train and evaluate a VGG19-based classifier for fungal microscopy images, then analyze performance with confusion matrix and ROC curves to identify strengths and failure modes.

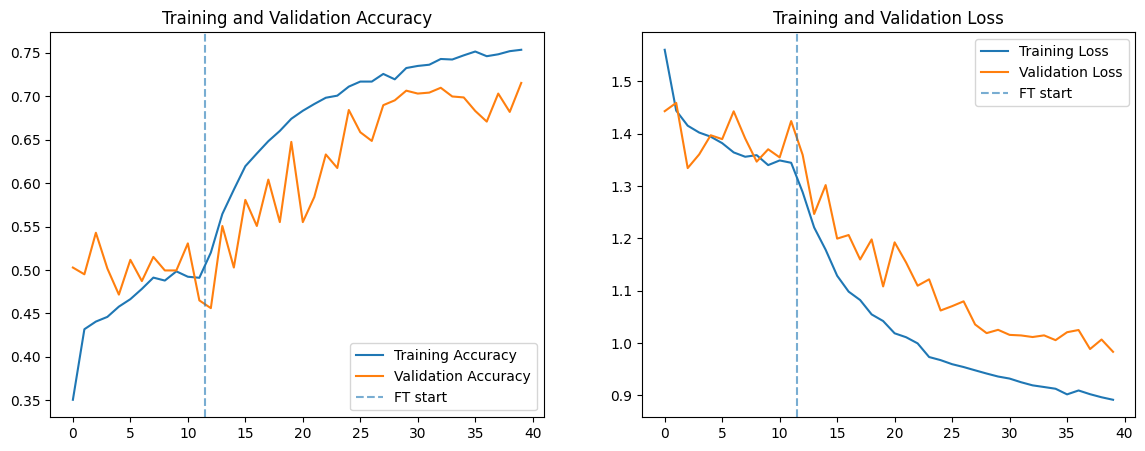
**1. Introduction**

VGG19 is a deep CNN with small 3×3 filters stacked across 19 layers. We use it via transfer learning: the ImageNet-pretrained convolutional trunk is reused and a light classification head is trained on our dataset. To improve generalization and stability, we (a) moved augmentations into the model (GPU-accelerated Keras layers), (b) replaced Flatten with GlobalAveragePooling2D, and (c) added Dropout, L2 weight decay, and label smoothing in the head.

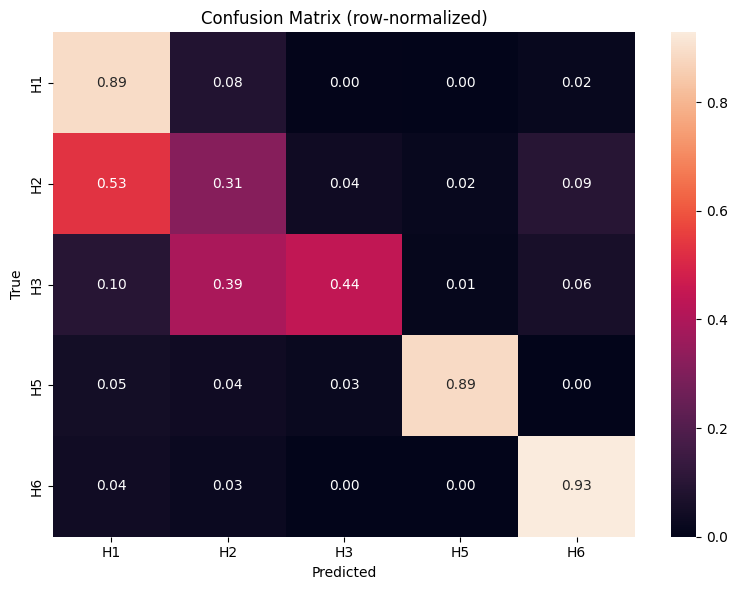
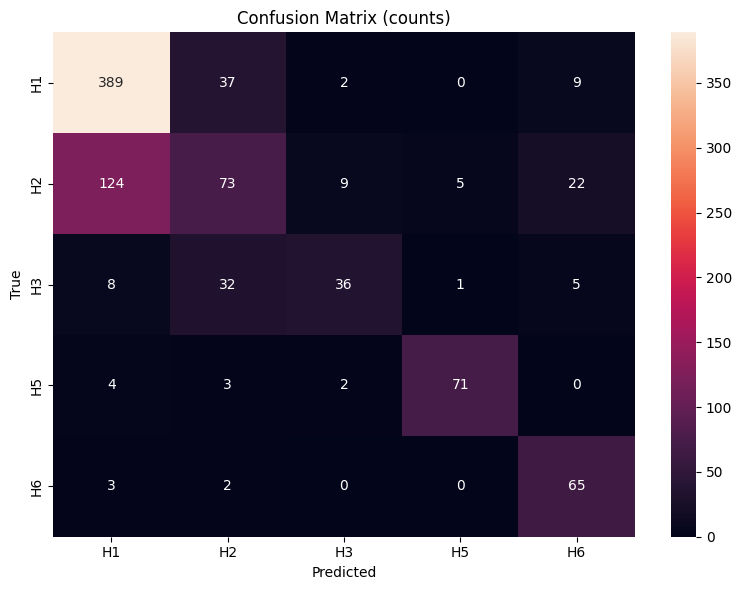
**2. Dataset**

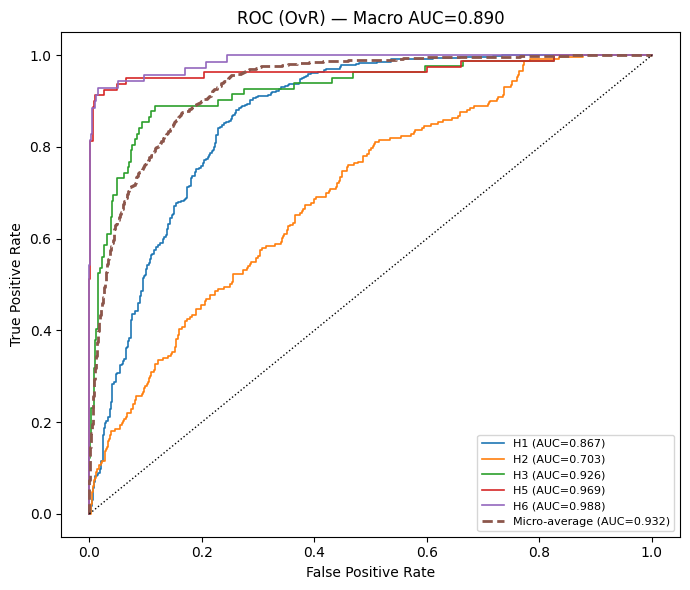
* Source: [Microscopic Fungi Image - DeFungi Dataset | Kaggle](https://www.kaggle.com/datasets/anshtanwar/microscopic-fungi-images)
* Classes: 5
* H1: Candida albicans  
    
  H2: Aspergillus niger  
    
  H3: Trichophyton rubrum  
    
  H5: Trichophyton mentagrophytes  
    
  H6: Epidermophyton floccosumTotal images: [Number]
* Preprocessing:
  + Resized images to 224×224 pixels
  + Normalized pixel values to range [0, 1]
  + Applied data augmentation (rotation, flipping, zooming) to improve generalization

**3. Methodology**

* **Model:** Backbone (VGG19): Pretrained feature extractor; include\_top=False; frozen first, then lightly fine-tuned later.
* **Head:** GAP → Dropout → Dense(512, ReLU, L2) → Dropout → Dense(C, Softmax) → low params + regularized probs.
* **Loss function:** Categorical cross-entropy with label smoothing (0.1) to curb overconfidence & improve generalization.
* **Optimizer/LR: Adam —** 1e-3 for head; 1e-5 when fine-tuning backbone (gentle updates).Batch size: 32
* **Epochs:** 40
* **Augmentations:** In-model RandomFlip/Rotation/Zoom → teach invariance; active only during training.
* 

**4. Results**

* **Training Accuracy:** Loss decreased steadily with stable validation behavior after LR reductions.
* The regularized head (GAP + Dropout + L2 + label smoothing) reduced overfitting compared to a Flatten-based head.
* **Test performance –**
* Overall test accuracy: 70.29%
* Macro F1: 70.67%
* ROC AUC: 0.932
* **Confusion matrix (high-level observations):**
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* **ROC:**

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**5. Conclusion**

The VGG19 transfer-learning pipeline forms a solid baseline for fungal species classification. Moving augmentations into the model, using GAP instead of Flatten, and adding regularization improved stability and generalization. The confusion matrix and ROC curves highlight specific class pairs that remain challenging. Next steps that typically lift accuracy further:

* Short fine-tune of VGG19’s block5\_\* (and optionally block4\_\*) at 1e-5 LR.
* Tuning batch size (16/32/64) and input size (e.g., 256×256) subject to VRAM.
* Class-weighting or minor sample rebalancing if some classes are underrepresented.
* Optional: Grad-CAM for qualitative interpretability on hardest confusions.