

Segmentation of Leukoaraiosis using Neural Network

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Introduction

Leukoaraiosis (LA) is a neurodegenerative disease that affects white matter in the brain. LA presents in MRI with a large signal intensity on a FLuid Attenuated Inversion Recovery (FLAIR) scan. However, mapping LA in the brain for further study and analysis can be tedious and results can vary based on human error. The goal of this project is to automate this process using an Artificial Neural Network (ANN) machine learning algorithm.

Artificial neural networks (ANNs) are designed with the concept of the human brain in mind; information is processed through the network to learn how to classify data. To assess LA identification accuracy, the ANN output is visually compared to hand drawn LA identification and both mathematically and visually compared to the output of another machine learning technique called Support Vector Machine (SVM).

Methods

Artificial neural networks (ANNs) are designed so that information is processed through the network to learn how to classify data. To assess LA identification accuracy, the ANN output is visually compared to hand drawn LA identification and both mathematically and visually compared to the output of another machine learning technique called Support Vector Machine (SVM).

We wrote an ANN program that trained with an equal number of confirmed LA or not LA locations. The network needs to be trained using a portion of all the data, so that the ANN can determine a threshold FLAIR value that will be used to qualify what parts of the brain have LA; The two arrays of unique FLAIR values and determined LA locations are used as the input and output, respectively, so that I train the program with the broadest and smallest range of FLAIR values possible to shorten the training time; doing this allows the network to narrow down that threshold FLAIR value. Based on the FLAIR value, the network would classify what locations in the brain were infected with LA. We then ran the MRI data from 11 brains through the network.

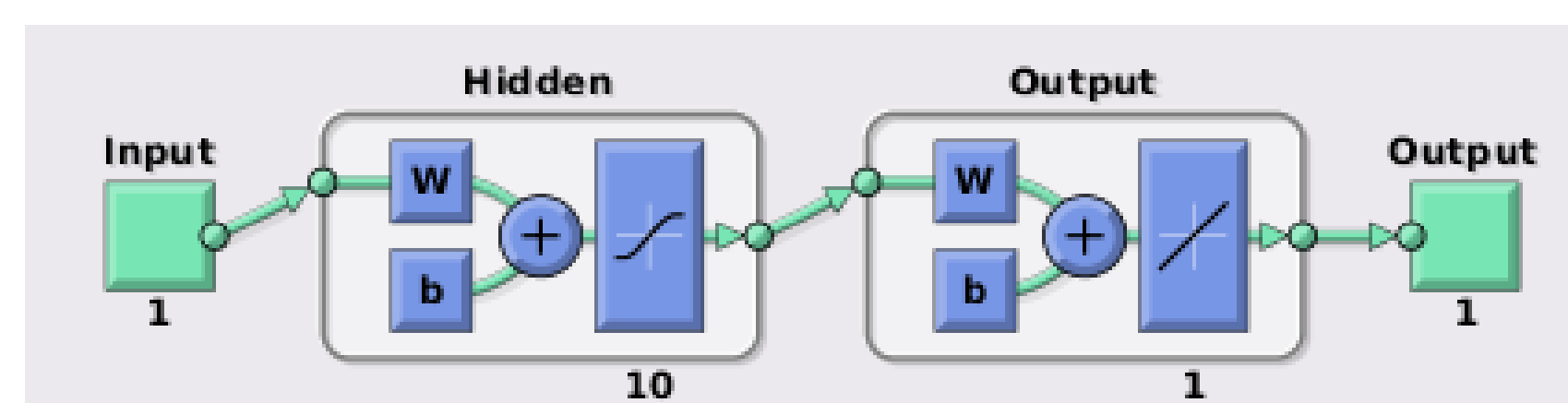


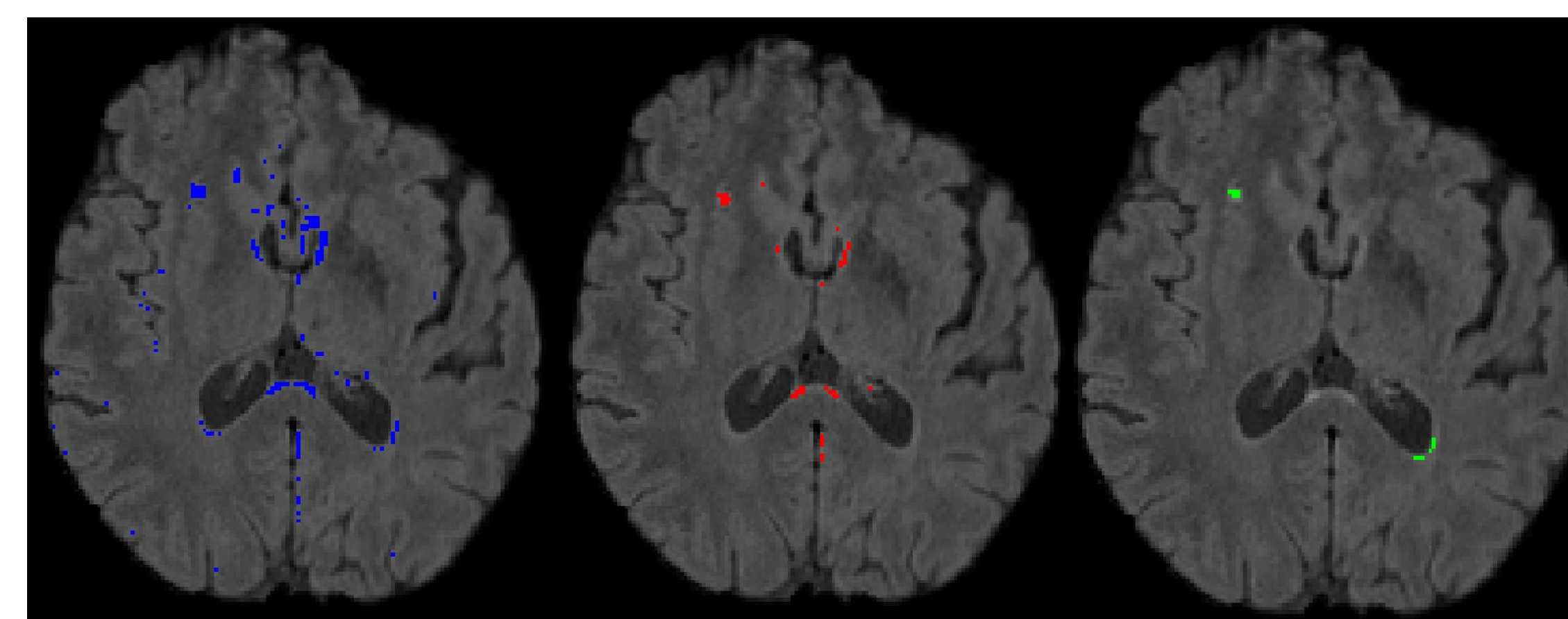
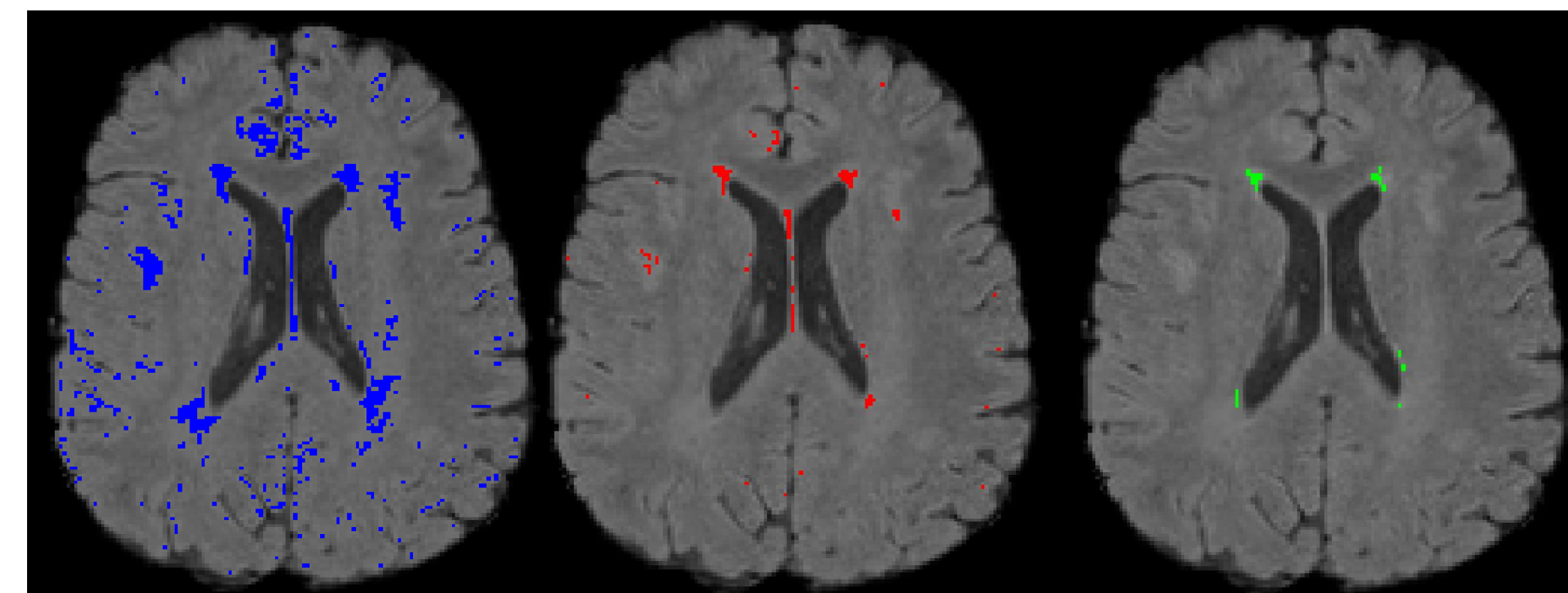
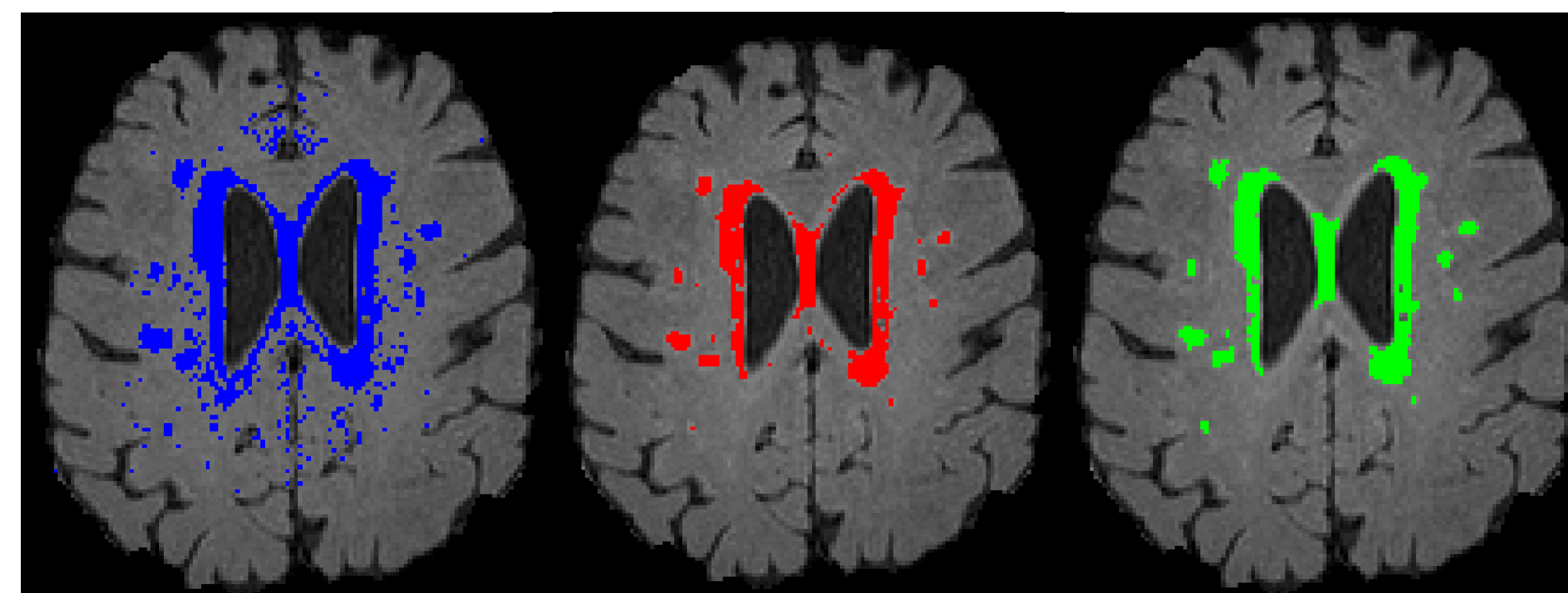
Figure 1 – Depiction of neural network training from MATLAB

Finally, the ANN output of each brain was compared to the SVM output, to obtain the ANN output accuracy. For further confirmation, we also created NIFTI files to view the ANN's LA mapping to visually compare the ANN LA mapping to both the hand-drawn and the SVM LA mapping.

All the code was created using MATLAB and the NIFTI files were viewed with FSL.

Results

Blue represents ANN LA mapping, red SVM mapping, and green hand-drawn mapping. The brains featured are TKA016, TKA023, TKA121, with accuracies of 98%, 99%, and 87%.



The mean accuracy of the ANN program when compared against the SVM LA mapping was 95%. It can also be seen that the ANN LA mapping catches LA locations that were missed in the hand-drawn mapping, while the SVM mapping is a lot less noisy compared to the ANN mapping.

Relevant Literature

- Della Nave, R., Foresti, S., Pratesi, A., Ginestroni, A., Inzitari, M., Salvadori, E., M., G., Diciotti, S., Inzitari, D., Mascalchi, M., 2007. Whole-Brain Histogram and Voxel-Based Analyses of Diffusion Tensor Imaging in Patients with Leukoaraiosis. American Journal of Neuroradiology, p. 1.
- Hagan, M.T., Demuth, H.B., Beale, M.H., De Jesus, O., 1996. Neural Network Design. Martin T. Hagan, Howard B. Demuth, Oklahoma State University, p. 1-1 – 1-9, 2-1 – 2-19, 11-1 – 11-26.

Conclusion

- LA segmentation by ANN has a high rate of accuracy, showing similar outputs to that of SVM.
- Visual comparisons of ANN and SVM segmentation correspond with the program's reported accuracy.
- Compared to the hand-drawn LA segmentation, the ANN segmentation seemed to have mapped the LA better.
- It can be assumed that the error may come from the network's training, since the SVM and ANN segmentation programs were trained in similar manners.

Future Directions

In the future, this program could be edited to be trained in different methods, by using a different training function that could determine a different classification threshold; another method would be to train the network using multiple brains to better understand the threshold FLAIR value that qualifies LA. Another issue with the output LA mapping of the ANN was how noisy the images were: while the mapping caught more LA locations than the hand-drawn, the SVM LA mapping was much cleaner and precise.

Furthermore, with how ANN and SVM map LA, I believe that these machine learning algorithms can be used to identify other neurodegenerative diseases and their origin points in the brain, and may help explain how these diseases are contracted.

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