Ophthalmology is a medical field ripe with opportunities for meaningful application of computer vision algorithms. The field utilizes data from multiple disparate imaging techniques, ranging from conventional cameras to tomography, comprising a diverse set of computer vision challenges. Computer vision has a rich history of techniques that can adequately meet many of these challenges. However, the field has undergone something of a revolution in recent times as deep learning techniques have sprung into the forefront following advances in GPU hardware. This development raises important questions regarding how to best leverage insights from both modern deep learning approaches and more classical computer vision approaches for a given problem. In this dissertation, we tackle challenging computer vision problems in ophthalmology using methods all across this spectrum. Perhaps our most significant work is a highly successful iris registration algorithm for use in laser eye surgery. This algorithm relies on matching features extracted from the structure tensor and a Gabor wavelet - a classically driven approach that does not utilize modern machine learning. However, drawing on insight from the deep learning revolution, we demonstrate successful application of backpropagation to optimize the registration significantly faster than the alternative of relying on finite differences. Towards the other end of the spectrum, we also present a novel framework for improving RANSAC segmentation algorithms by utilizing a convolutional neural network (CNN) trained on a RANSAC-based loss function. Finally, we apply state-of-the-art deep learning methods to solve the problem of pathological fluid detection in optical coherence tomography images of the human retina, using a novel retina-specific data augmentation technique to greatly expand the data set. Altogether, our work demonstrates benefits of applying a holistic view of computer vision, which leverages deep learning and associated insights without neglecting techniques and insights from the previous era.