

Symposium – International Academy of Digital Pathology (IADP)

## The use of virtual microscopy and a wiki in pathology education: Tracking student use, involvement, and response

Zev Leifer

Department of Pre-clinical Sciences, New York College of Podiatric Medicine, New York, NY 10035, USA

E-mail: \*Dr. Zev Leifer - [zleifer@nycpm.edu](mailto:zleifer@nycpm.edu)

\*Corresponding author

Received: 11 March 15

Accepted: 19 March 15

Published: 03 June 2015

### This article may be cited as:

Leifer Z. The use of virtual microscopy and a wiki in pathology education: Tracking student use, involvement, and response. J Pathol Inform 2015;6:30.

Available FREE in open access from: <http://www.jpathinformatics.org/text.asp?2015/6/1/30/158063>

Copyright: © 2015 Leifer Z. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

### Abstract

**Background:** The pathology laboratory course at the New York College of Podiatric Medicine involves the use of Virtual Microscopy. The students can scan the whole slide, section by section, and zoom in or out. **Methods:** Using the advantages of digital pathology, the students can, in addition, access the slide collections from other medical schools and put up normal histology (control) slides side-by-side with the pathology. They can cut and paste and preserve the region of interest that they find. They can edit and annotate their slides. A wiki was created (<http://pathlab2014.wikifoundry.com>) for the Class of 2014. The students saved, edited and uploaded their slides. In the wiki format, other students could comment, further edit, and even delete the slides. **Results:** The students studied Basic Mechanisms and System Pathology. During this time, they saved, edited, shared, and uploaded their slides to the wiki. These were available in one full presentation and were also grouped into 16 albums. They were available to all. Student access was followed by Google analytics. At the end of the course, a questionnaire was distributed, assessing their impression of the wiki format and soliciting strengths and weaknesses. **Conclusions:** The use of a wiki has a number of important advantages in pathology education. It trains the students in the more sophisticated skills that they will use as professional pathologists or as clinicians: (1) Telepathology-it enables them to share slides and discuss observations. (2) Archiving and retrieval - It models the challenge faced by hospitals, diagnostic labs and physicians in maintaining a collection of slides in a form that is easily accessible. (3) Image analysis-familiarity with the wiki format allows them to jump easily to capturing and storing images found in the literature or in a pathologist's report. Experience with the use of a wiki in pathology education has been quite satisfactory from both the faculty and the student's point of view.

**Key words:** Digital pathology, pathology education, telepathology, virtual microscopy, wiki

### Access this article online

#### Website:

[www.jpathinformatics.org](http://www.jpathinformatics.org)

DOI: 10.4103/2153-3539.158063

#### Quick Response Code:



### INTRODUCTION

Diagnostic Pathology has changed dramatically in the past decade. With the advent of Digital Pathology<sup>[1]</sup> many new capabilities, including Telepathology, Archiving

and Retrieval, Image Annotation, Image Analysis and Professional Collaboration have facilitated and/or expanded the professional lives of pathologists. In conjunction with these developments, medical school pathology education, especially in the laboratory, has

moved into the digital age.<sup>[2,3]</sup> This applies, in its own right, as an advanced didactic methodology. Even more so, it prepares, not only the pathologist-to-be (probably a small fraction of any given medical school class) but, in a larger sense, prepares all of them, clinicians-to-be, for the digital pathology world that awaits them. This aspect of their training has been addressed in their training at the New York College of Podiatric Medicine (NYCPM).

The Pathology Laboratory course at NYCPM consists of 17 2-h sessions, covering Basic Pathological Mechanisms and Systemic Pathology. Each session has three essential parts. Initially, a brief opening presentation outlines the particular features of the pathology to be studied. The bulk of the time is spent by the students, in working groups of four. In addition to the assigned slides, their study is supplemented by assigned images in atlases given as mandatory texts<sup>[4]</sup> or as atlases made available by the professor in the “class library”. These include the atlases by Curran, Thomas, and Damjanov.<sup>[5-7]</sup> In addition, slides are assigned from other online sites, as will be discussed below. The final part of the session consists of a conference. New slides (not previously studied, but of the same subject matter) are put up on the screen. The format, roughly, is as follows: “What is your diagnosis?” Student A thinks it is this. Student B thinks it is that. To Student A: “What is your reasoning, what is the basis of your conclusion?” Same to Student B. To Student A: “What do you do with Student B’s observation and conclusion? To Student B the same regarding A’s comments. Hands go up, and the rest of the class joins in on the pros and cons of each side. At the end, the professor identifies the pathology and the defect in A’s (or B’s) reasoning.

The process of studying the pathology laboratory images is inherently and significantly different from what they get from looking at a lecture PowerPoint image or an image found in a text or atlas. The latter are usually static, close-up, idealized images of the pathology in question, showing the important aspects. On the other hand, in the lab several important differences are inherently present and are didactically emphasized. In a slide, usually much of the slide is, in fact, normal tissue. It is the student’s responsibility to know the differences between normal and abnormal, to scan the entire slide, find the area of pathology and then zoom in and study it. In this regard, they are taught to start at a low power to find the region of interest (ROI), and then raise the magnification to study it in greater detail. Starting at a high power may mean that they miss the ROI entirely. Secondly, in some cases, there may be more than one pathology on the same slide. Their job is to know the features of the pathology under study, note the other, identify it and then disregard it as not relevant. Finally, the point is made that in many cases the immediate cause of the pathology is not visible (e.g., the sand particle in silicosis) but they can

tell that it is there and where it is located by the body’s response to it (fibrotic nodule) [Table 1].

The above comments describe a pathology lab as presented at NYCPM and classically, for over a century, studying glass slides with a microscope. The relevance of this section will be discussed in “conclusions”, below.

## METHODS

Several years ago, NYCPM switched to Virtual Microscopy (Digital Pathology) in its (Histology and) Pathology laboratory course. That has enabled numerous changes in the way that the course is presented. These changes have greatly enhanced the educational component of the experience. The 105 slides in the course were digitized (WSI) by the Olympus Corporation and made available in-house, with their software, for PCs (Windows) and Mac laptops and via Olympus’ Olyvia viewer for the iPad mini. WiFi in the lab makes it all available without a forest of cables and connections. Minimally, the computer works like a microscope – the students can move up, down, left and right. They can increase the magnification by multiple means.

### However, the Digital Age has Changed Much in the Details of Pathology Lab Presentation

In general (1) the digital slide collection is portable, always accessible to the student, at home or away, that is, one laptop compared to a heavy microscope and a box of slides. All slides are available instead of, as is often the case, sharing a collection of slides; (2) the slides are safe, compared to the danger of dropping or otherwise damaging the fragile slide collection; (3) the slides are equal, all students (per group, per section, per year) having the exact same slides, compared to many cases, especially with older slide collections, where different

**Table 1: Aspects of laboratory slide analysis that differ from a text, lecture slide or journal static image**

Much of the slide is normal tissue. The student’s role is to know the differences between normal and abnormal; scan the entire slide, locate the pathology (ROI) and study it at varying levels of magnification
There may be more than one pathology on the same slide. The student’s role is to know the particular features of the pathology under discussion and to disregard other observations, even though present, as not relevant
Know that in some cases, the immediate cause of the pathology may not be visible, e.g., the sand particle in silicosis but the student should know where it is to be found by the body’s response to it (fibrotic nodule)
As an operational strategy, start at the lowest power and work up to higher magnification. Going too “close” too soon may result in missing the pathology completely

ROI: Region of interest

slides are ordered or prepared, nominally of the same pathology, but not the same slide with the same features in the same location. This may not make a difference for diagnosis, but for teaching (“everybody look at the top right corner next to the blood vessel”) a different slide could present great difficulty.

In particular at NYCPM: (1) The students have in-house (courtesy of Olympus) access to the collections of many other medical institutions (Mount Sinai School of Medicine, Albert Einstein College of Medicine, Ben Gurion University). By Web links, they are assigned slides at other institutions as well (University of Indiana (<http://medsci.indiana.edu/c602web/602/c602web/toc.htm>), University of Iowa (<http://www.path.uiowa.edu/virtualslidebox>. Requires Biolucida Slide Viewer <http://www.biolucida.net>). All of these have their collections publicly available and are in the Virtual Microscopy format. Many have both histology and pathology collections; (2) the students are assigned normal histology slides to go along with the parallel pathology slide (“you can’t appreciate the pathological unless you know what the normal is supposed to look like”). They can split the screen and have normal and abnormal in front of them at the same time. They can open two screens and toggle back and forth if they can’t split the screen. So far – just enhanced studying. The next level is enhanced slides.

## The Preparation of Value-added Slides

### Slide Capture

By various strategies [Table 2] the students can capture the slide, as the whole slide (crop later) or as a cropped ROI on the slide.

### Slide Editing/Annotation

By various built-in or readily available software programs, the captured slides can be manipulated and modified (value-added slides) [Table 3]. They can crop, underline, circle, and box the important aspect of the pathology. They can add arrows and text.

### Slide Presentation

They can save and present this product to an MS Word document or to a PowerPoint presentation. They can store it in Google Drive [Table 4]. Very often these value-added slides are appended to the document they constructed at the start of the session, with the lecture description of the salient features that they should look for, now enhanced with the results of what they found [Figures 1 and 2].

### Slide Sharing

They share their products with each other, now not just enhanced images but enhanced presentations, via E-mail or shared links [Table 5].

## The Preparation and Use of a Wiki

To carry all of the above to the next step, a wiki was made available to the students and was populated by

### Table 2: Slide capture

PC
Print screen (entire screen)
Snipping tool (selected area)
MAC
Command-shift-3 (entire; to desktop)
Command-shift-4 (selected; to desktop)
iPad mini
“Two-button click”

PC: Personal computer, MAC: Macintosh personal computer

### Table 3: Slide editing/annotation

PC
Paint
PowerPoint
Image Manager
Adobe Acrobat
MAC
Preview
Annotate
iPad mini
Notability

PC: Personal computer, MAC: Macintosh personal computer

### Table 4: Slide presentation

Save/copy to
Word document
PowerPoint presentation
Google drive

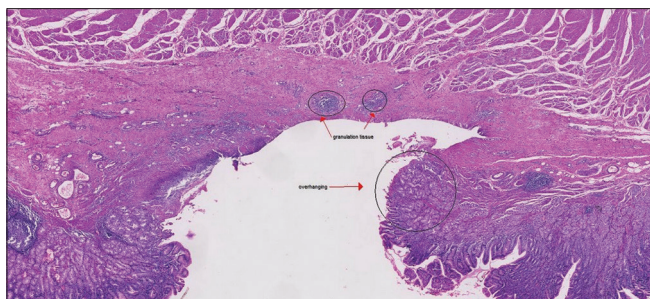
their slides, many of which were value-added by editing and annotation.

A wiki (Wikipedia is an example) is a website wherein all in a large group can access the site, submit material, edit each other’s material, and comment on the submissions. There are a number of publicly available sites that provide the template for this capability. Wikifoundry and Wikispaces are two (links listed in Table 6).

### A Wiki was Created for the Pathology Lab for the Class of 2014 – <http://pathlab2014.wikifoundry.com>

The students saved, edited and uploaded their slides. In the wiki format, other students could comment, edit and even delete the slides. In all, 216 images were uploaded [Figure 3]. These were available in one full presentation (See Photos on the Website) [Figure 4]. This collection was also grouped into the 16 sessions/topics of the course (GI, Respiratory, etc.) (See Albums, within Photos) [Figure 5].

The WSI format is for uniform viewing of the fixed slide collection. All students (and only NYCPM students, via password) see the same slides. For enhanced (“value-added slides”), the slide, totally or partially, is captured, saved



**Figure 1: Acute gastric ulcer. Student's cropped and annotated slide in the wiki. Note circles, arrows, labeling. Note selection of region of interest**

### Table 5: Slide sharing

E-mail
Word documents
PowerPoint presentations
Upload to common sites
Google drive
Dropbox
Wiki (see text to follow)

### Table 6: Freely available sites for the construction of a wiki

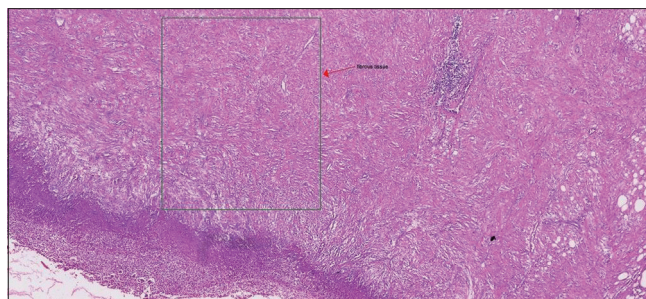
Wikifoundry	<a href="http://www.wikifoundrycentral.com">http://www.wikifoundrycentral.com</a>
Wikispaces	<a href="https://www.wikispaces.com">https://www.wikispaces.com</a>
Wikidot	<a href="http://www.wikidot.com">http://www.wikidot.com</a>

and edited and then added to the wiki collection (see above). The wiki is publicly available (albeit modifiable only by the class). This is the repository of the edited slides, in the form of a total collection (“photos”) or a categorized collection (“albums”). There is no public access to the WSI collection nor can the slides there be value-added in a publicly available or group-modifiable fashion. Hence, the advantages of the wiki.

From the educational perspective, the use, involvement, and response were also monitored.

With the digital capabilities of Google Analytics, student use of the wiki website was followed. Many parameters were available given the same GA database. One could look at sessions per date or time frame, average time per session, average pages per session and so on (a sample is shown in Figure 6). This provided a detailed analysis of student use.

In addition, at the end of the course, a questionnaire was distributed, assessing the student’s impression of the wiki format and soliciting strengths and weaknesses. Approximately one hundred sets of comments were obtained. Most comments were favorable. Negative



**Figure 2: Chronic gastric ulcer. Student's cropped and annotated slide in the wiki. Note box. Note selection of region of interest**

comments were mostly directed to technical issues of accessing and using the site [Tables 7 and 8].

In other institutions, variations of these ideas have been used. At New York University Medical Center, the Virtual Microscopy slide collection can be annotated by students and faculty “in situ” as a pop-up on the slide. A voting system allows annotations to be “voted up or voted down (and removed).”<sup>[8]</sup> At the University of Pittsburg Medical Center, a wiki was used for students in a genomics, research and pathology informatics course to write online review articles on assigned lectures.<sup>[9]</sup> At Massachusetts General Hospital/Harvard Medical School, a wiki was used to comment on their pathology curriculum and the pathology-relevant articles found in Wikipedia.<sup>[10]</sup> No reference to a wiki, such as described here, for student extensively-edited-and-organized slides, was found.

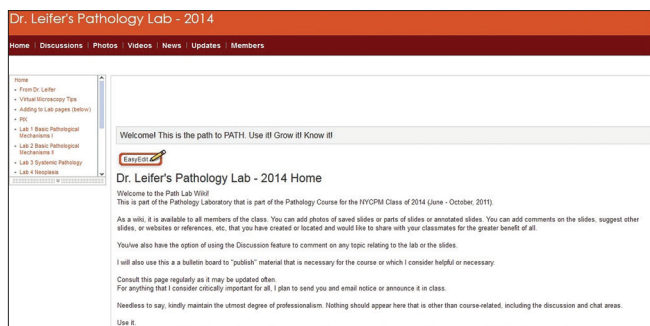
## CONCLUSIONS

The use of digital pathology in the classroom has a number of important advantages in pathology education. In addition to enhancing the in-lab real-time experience, it trains them in the more sophisticated skills that they will use as professional pathologists or clinicians.

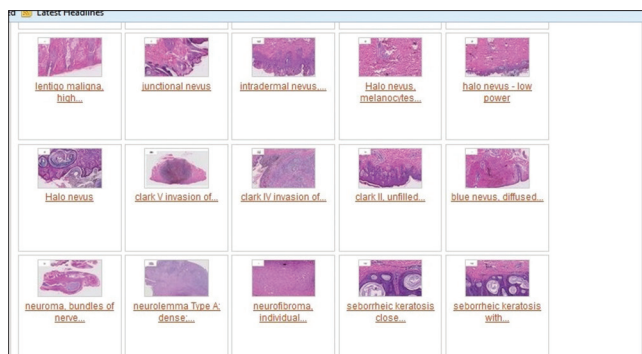
### Slide Analysis via Digital Pathology

For the future pathologist, this is obviously critical to his/her training in looking at slides using the computer (especially when the FDA approves Digital Pathology for primary diagnosis in the U.S.<sup>[11,12]</sup>). Even today, Digital Pathology is being used for in-sourcing, that is, U.S. Pathology Departments (e.g. The Cleveland Clinic, The University of Pittsburg and Johns Hopkins University) engage in secondary diagnosis of slides originating in the U.S. or primary diagnosis/consultation on slides coming from foreign countries, especially those that do not have adequate pathology services of their own. Certainly, for research, much is done using the digital format.

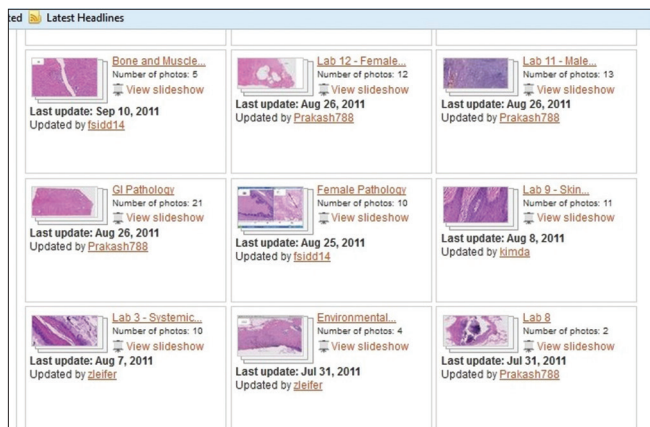
Other applications for the pathologist, in addition to his bread-and-butter diagnostics, might be keeping a digital “resident’s slide box”. SAGE (Scalable Adaptive Graphics Environment<sup>[13]</sup>) is a multiscreen presentation on a large wall with a single presentation or multiple data



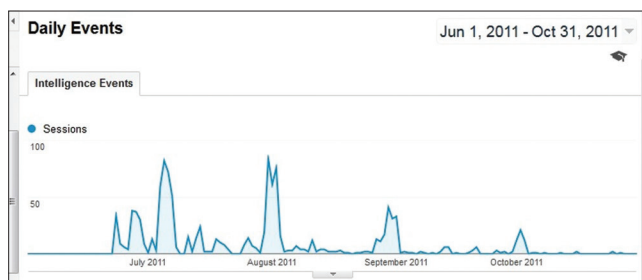
**Figure 3: Homepage of the wiki described in this work. Created for and by the New York College of Podiatric Medicine Class of 2014 (June–October, 2011)**



**Figure 4: A sample of the slides in the photos section of the wiki. Uploaded by the students. Many are annotated by the students**



**Figure 5: A sample of the slides organized in the albums section of the wiki. Arranged by the students according to topic or organ system**



**Figure 6: A sample screen-shot taken from the Google analytics website. Shows usage per day during the course**

contents. It has been adapted<sup>[14]</sup> for Whole Slide Image presentation, involving one virtual slide, suitable for group viewing and manipulation (for consultation, education or Grand Rounds discussion) or multisource input (a large group version of the “pathologist’s cockpit” (see image in<sup>[15]</sup>) or to facilitate telepathology conferencing.

However, what about those who will not be professional pathologists? Several applications may be suggested:

**Virtual Images in Journal Articles**

The journal Diagnostic Pathology<sup>[16]</sup> requires that all images be made available in Virtual Microscopy format. A recent article in Archives of Pathology and Laboratory Medicine<sup>[17]</sup> has digital images.

http://goo.gl/17xEnf. An editorial by Cagle and Glassy<sup>[18]</sup> puts this new format into perspective. It follows that professionals, reading such a paper will benefit from (must have) the skills that they learn in a VM/DP lab in medical school. The skills referenced in Table 1 here become of critical importance.

**Virtual Images in Pathology Reports**

Routinely, clinicians will be sending out their biopsy samples to the pathology lab and receiving a pathologist’s report in return. In addition to the text description of the

pathologist’s observations and the usual static images of the ROI, today, and increasingly, diagnostic labs will be including, if not an embedded virtual image, at least a link (with appropriate passwords and HIPPA security) to the slide in the lab’s archives, and hence the clinician can see the actual slide, scan it all around, and obtain his own impression (based on the skills of manipulation and slide analysis learned in a digital lab in medical school). Not that his opinion will overrule the pathologist, who has devoted his professional life to honing these skills, and not that every clinician will be so inclined. Yet, some will, and the case may arise where a clinician with such an interest and ability, may make an observation that perhaps the lab did not consider and at least have the basis to not only enter into a professional discussion, but digitally, both can look at and manipulate the same slide at the same time (e.g. Vision Tek, by Sakura<sup>[19]</sup>). Currently, Ventana and SunQuest (personal communication) are working to build this capability into their Pathologist’s Report. Again, reference the comments in Table 1.

**The Use of a Wiki in the Training of Both Pathologists and Clinicians**

In the digital world to come (and very much here now), there are several applications of a wiki in classroom training to the post medical school world.

**Telepathology**

This is the ability to look at slides, digitally, over large distances, with two or more pathologists looking at the same slide at the same time. This is relevant to Tumor

**Table 7: The questionnaire: Sample positive comments**


---

Ease of use  
 Sharing of “best slides”  
 Multiple images of same pathology  
 Aids in exam preparation  
 Helps if student “couldn’t find the pathology”  
 Access outside of class

---

**Table 8: The questionnaire: Sample negative comments**


---

Technical issues  
 Website down occasionally  
 Website slow when there are many users  
 There is a learning curve – e.g., how to upload images  
 There are student errors – better editing is needed  
 There are some students who are major contributors; need more input from all  
 There is a need for more organization – “who does what”

---

Boards and to consultations. From foreign countries, as long as they have WSI capability to the extent that they can digitize a slide and have the software to upload it to a common site, from a medical school in Egypt to a diagnostic center in Italy,<sup>[20]</sup> from a site in China to a lab in Cleveland or Baltimore, the collaboration can take place.

At the clinician’s level, he may want to consult (as above) with the pathology lab or get a second opinion from another pathologist. The availability of the digital pathology technology will enable that to take place.

Training in medical school via a wiki, as described here, can prepare the pathologist to be comfortable with the use of long-distance interaction and consultation (Granted, the wiki images are static, but the lessons and comfort-level training are applicable).

**Archiving and Retrieval**

When compared to mountains of glass slides in cabinets and drawers, and the inherent difficulty in managing, locating and obtaining a particular slide, now, with Digital Pathology, the job is greatly simplified. With appropriate software and careful initial logging in, a pathologist can locate any slide within seconds. He can compare today’s slide with the patient’s slide from a year ago to assess the effectiveness of treatment or the development of the disease. The clinician, as well, albeit not to anywhere near the same extent, may have his own collection of slides of interest for particular cases. The job of archiving and retrieving is similar in principle and need, if not in volume. The training of both, with a wiki they used in pathology lab in medical school, provides the experience with a collection of images that is easily accessible, always available and universally shareable. With the album

feature, slides can be stored in large numbers, cataloged by patient name, by pathology, by tissue type, and so on. All this is preparation for their future professional activities.

**Image Analysis**

While not generally used in an undergraduate laboratory, familiarity with a wiki format allows them to easily jump to capturing and storing images found in the literature, or provided by colleagues, that have been stained for tumor markers or other diagnostic staining techniques (e.g.,<sup>[21]</sup>).

**SUMMARY**

Experience at the NYCPM Pathology Laboratory in the use of Digital Pathology in general and the use a wiki designed for the course in particular has been satisfactory from both the faculty and the student point of view. It has a number of training advantages in the ever-expanding world of Digital Pathology.

As the world of slide analysis is moving towards a fuller use of digital pathology, medical education must keep up. The ideas presented here suggest ways in which future pathologists and clinicians can be trained in the concepts and techniques that will be part of the Digital World that will be their future.

This work was originally presented in poster format at the Annual Meeting of the Digital Pathology Association (Pathology Visions 2013, San Antonio, TX). It was featured in the monograph “Digital Pathology”<sup>[1]</sup> in its section on “Digital Pathology as a Teaching Tool” (see section 5.2.2). In expanded form, it was a platform presentation at the Second Congress of the International Academy of Digital Pathology (These Proceeding; abstract published<sup>[22]</sup>).

**ACKNOWLEDGMENTS**

The author gratefully acknowledges the contributions of the following members of the NYCPM Class of 2014.

Contributing slides to the wiki: Faysal Siddiqui, Prakash Panchani, Raisa Kiperman, Elizabeth Jiang, Dae Kim, Yuching Chi, Hanya Almudallal, Michael Gazes, Ana Pimental-Tejeda, Mark Berkovic, Jessica Olson, Anshini Dalal, Yekaterina Narodetskaya, Nina Klein, Ben Suh and Elizabeth Jacob.

Contributing to the Lab Notes write-ups: Mark Berkovic, Michael Gartenhaus, Timothy Bui, Aniseal Hashemi, Meltem Ates and Faysal Siddiqui.

Contributing to the Discussion Threads: Lauren Dabakaroff, Nina Klein, Faysal Siddiqui, Jonathan Roy and Eric Nelson.

Contributing to the Slide capture/Annotation/Presenting/ Sharing section: Class of 2014 – Meltem Ates, Georgios Kotzias, Prakash Panchani, Ben Suh, Chelsea Viola, Faysal Siddiqui, Hanya Almudallal and Poovasis Klinoubol. Class of 2016 –

Sarah Mohammed, Kelly Noonan, Magdalene Armanious, Nkechinyere Nwoko, Naeemah Ruffin, Sarah Cathcart, Zachary Sax, Xiomara Okonkwu, Amanda Riley, Brittany Ciaramello, Nam Tran, Michelle Kaufman, Elizabeth Bonarigo, Kiana Karbasi, Brittany Mayer, Caitlin Miner, Regina Fiacco, Donal Erickson, An Nguyen and Wei-Jei Liao. Class of 2017 – Erin Kunz, James Chung and Svetlana Eydelman.

## REFERENCES

1. Sucaet Y, Waelput W. Digital Pathology. New York: Springer; 2014.
2. Dee FR. Virtual microscopy in pathology education. *Hum Pathol* 2014;40:1112-21.
3. Pantanowitz L, Szymas J, Yagi Y, Wilbur D. Whole slide imaging for educational purposes. *J Pathol Inform* 2012;3:46.
4. Young B, Stewart W, O'Dowd G. Wheeler's Basic Pathology: A text, Atlas and Review of Histopathology. 5<sup>th</sup> ed. London: Churchill Livingstone/Elsevier; 2011.
5. Curran RC, Crocker J. Curran's Atlas of Histopathology. 4<sup>th</sup> ed. London: Harvey Miller/Oxford University Press; 2000.
6. Thomas C. Sandritter: Histopathology. 8<sup>th</sup> ed. Philadelphia: B.C. Decker, Inc.; 1989.
7. Damjanov I. Histopathology: A Color Atlas and Textbook. Baltimore: Williams and Wilkins; 1996.
8. Triola MM, Holoway WJ. Enhanced virtual microscopy for collaborative education. *BMC Med Educ* 2011;11:4.
9. Park S, Parwani A, MacPherson T, Pantanowitz L. Use of a wiki as an interactive teaching tool in pathology residency education: Experience with a genomics, research, and informatics in pathology course. *J Pathol Inform* 2012;3:32.
10. Kim JY, Gudewicz TM, Dighe TS, Gilbertson JR. The pathology informatics curriculum wiki: Harnessing the power of user-generated content. *J Pathol Inform* 2010;13:1.
11. Lusky K. Where will FDA land on whole-slide digital? *CAP Today* 2009;23:1.
12. Parwani AV, Hassell L, Glassy E, Pantanowitz L. Regulatory barriers surrounding the use of whole slide imaging in the United States of America. *J Pathol Inform* 2014;5:38.
13. Jeong B, Leigh J, Johnson A, Renambot L, Brown M, Jagodic R, et al. Ultrascale collaborative visualization using a display-rich global cyberinfrastructure. *IEEE Comput Graph Appl* 2010;30:71-83.
14. Levy B, Mateevitsi V. Scalable Adaptive Graphics Environment (SAGE): a Novel Way to View and Manipulate Whole-slide Images. [abstract]. Proceedings of the 2<sup>nd</sup> Congress of the International Academy of Digital Pathology; 2010. p. xxi.
15. Soenksen D. Digital pathology at the crossroads of major health care trends: Corporate innovation as an engine for change. *Arch Pathol Lab Med* 2009;133:555-9.
16. Diagnostic Pathology. Available from: <http://www.diagnosticpathology.org>. [Last accessed on 2015 Jan 05].
17. Hwang DH, Szeto DP, Perry AS, Bruce JL, Scholl LM. Pulmonary large cell carcinoma lacking squamous differentiation is clinicopathologically indistinguishable from solid-subtype adenocarcinoma. *Arch Pathol Lab Med* 2014;138:626-35.
18. Cagle PT, Glassy EF. Whole slide images add value to journal article figures. *Arch Pathol Lab Med* 2014;138:592-3.
19. Digital Microscope Brightfield System. Available from: <http://www.sakuracom.com>. [Last accessed on 2015 Jan 05].
20. Ayad E, Sicurello F. Telepathology in emerging countries pilot project between Italy and Egypt. *Diagn Pathol* 2008;3:S2.
21. Angelo M, Bendall SC, Finck R, Hale MB, Hitzman C, Borowsky AD, et al. Multiplexed ion beam imaging of human breast tumors. *Nat Med* 2014;20:436-42.
22. Leifer Z. The use of virtual microscopy and a wiki in pathology education: Tracking student use, involvement and response. [Abstract] *Anal Cell Pathol* 2014;2014:274134. [Epub 2014 Nov 23].