What can we envision automating in the anatomic pathology laboratory? The big picture of automation in anatomic pathology is difficult to understand if we compare it to the way that we think about automation in clinical pathology using the typical concepts of pre-analytic, analytic and post-analytic processing. While anatomic pathology can be thought of as having analytic, post-analytic as well as pre-analytic phases these terms don’t necessarily apply clearly like they might in the clinical chemistry laboratory. For example where does the analytic process actually begin in anatomic pathology? Does it begin at the gross examination or is the gross examination actually a preanalytic process designed to pre-process tissue for the histology laboratory? What about histologic staining? Is histologic staining analytic or preanalytic? In many cases, histologic staining could be considered an analytic process because analysis is happening at the time the tissues are actually being stained. While this organization can help our thinking, it is not really a perfect match for anatomic pathology. There are exceptions to this in clinical pathology as well. For example when we look at a tube of blood we can notice that the tube of blood is actually lipemic (analytic). While it is easy to think of in terms of pre-analytic, analytic, and post-analytic, it is not really a good fit for thinking about automation in anatomic pathology.

A workflow vision might be more helpful. For example automation systems “external to the laboratory prior to diagnoses” such as:

- the clinical order
- transport
- specimen receipt

“Processes internal to the laboratory” such as:

- case accessioning, labeling,
- gross exam
- quality assurance.

And finally, “processes external to the laboratory following diagnosis” such as:

- clinical reporting,
- automated notification
- data integration with other systems.

For this talk, most of my examples will focus on processes internal to the laboratory where automation is beginning to be implemented.
What can we envision automating in its entirety? If we start from the beginning of the anatomic pathology process from the electronic order flow into the anatomic pathology system to the end of the process where the surgical pathology material are returned to the filing room, different steps may include:

- electronic order to the AP LIS,
- biopsy and label
- transporting of the specimen
- accessioning the specimen
- tissue gross exam
- processing including fixation, embedding of the tissue
- cutting tissue and labeling the slides
- staining and cover slipping the slides
- case collation
- delivery of the slides to the pathologist
- the microscopic exam of tissue
- staining and recutting slides for additional sections
- dictation of case information
- transcription of case information
- signing out of the surgical pathology report
- clinical report delivery
- filing of material into the histology (blocks and slides)
- retrieval material for additional studies

Each of these areas is amenable to automation and as we will see, many of these areas have already had automation implemented.

When we think about automation in the anatomic pathology laboratory, it is helpful to consider prerequisites systems and development that will impact adoption. This actually begs the question as to why has the anatomic pathology laboratory lagged so far behind the clinical pathology laboratory in terms of implementing pathology automation? Perhaps the most important reason for this is the harsh environment in which anatomical pathology laboratories work. Many people highlight the fact that specimens are highly variable and the extensively manual processes as reasons for lack of automation. It also has to be accepted that anatomic pathologists have not been particularly motivated to develop automation for the anatomic pathology laboratory. However, I believe the most important reason that these anatomic pathology laboratories have not been automated is due to the harsh environment in the gross room and the histology laboratory. This has included the lack of ability to label cassettes or slides prior to staining due to the fact that these labels would typically would not survive the staining process. Additional prerequisites include sophisticated electronic medical record systems, electronic orders interfaces with anatomic pathology ordering systems, barcoded label assets within the laboratory, and that includes assets with unique identifiers, and further the development of robotic technology. Let’s look at these in a little bit more detail.
Sophisticated electronic medical records systems are important because these systems will enable clinical orders to be sent directly to the anatomic pathology information system such electronic ordering systems should also support decision support, gathering of accurate required information, potentially be linked with positive patient identification systems or allow for the generation of laboratory ready labels at the point of service and will allow samples to be tracked from the laboratory to the point of clinical service. In addition, electronic orders into the anatomic pathology information system are critical since these orders when placed by clinicians from the EMR will allow the anatomic pathology system to behave similar to the clinical laboratory with the flow of orders into the LIS automatically enabling sample tracking and receipt, routing of samples, processing of samples and automation of several elements of case accessioning allowing for decreased errors and increased throughput in the anatomic pathology laboratory.

Critical for all of these processes is the generation of barcode labeled assets within the laboratory. This is the most essential early prerequisite to achieve and will be required for all of the other aspects of anatomic pathology lab automation to be accomplished. Barcoding of assets will allow for barcode driven workflow, reduce errors due to mislabeling, and improve efficiency by reducing manual labeling. Further in order to achieve automation of subsequent activities such integration of whole slide imaging or automated histology staining, bar code labeled assets are the cornerstone. This is a key requirement for almost all of the automation steps that we will talk about today. Barcode labels should be thought to include the requirement that each barcode to uniquely identify an asset by using a unique barcode identifier specific for each labeled item. This ultimately allows each block and slide to be managed independently allowing for sophisticated routing and tracking. This is essential for such technologies as digital pathology. In addition, barcode labeling of assets will allow interfaces to instruments allowing for automation of staining and routing as well as post processing of slides. Without uniquely identified assets, the clinical laboratory could not have achieved the level of automation currently experienced. Thus, this is a critical prerequisite for anatomic pathology automation.

The development of robotic technologies is critical as well, however, robotic technologies will evolve slowly in a variety of different areas including the ability to auto embed, the ability to auto section using robotic microtomes, and perhaps even the ability to automatically gross specimens or to at least use robots to assist in grossed sections, automated sampling of blocks, and automated slide sampling. In fact with the exception of grossing, the rest of these robotics technologies already exist, albeit in relatively simple instruments that are not well adopted yet. Block and slide sampling is particularly well developed including laser capture microdissection of slides for sampling tissue. Early examples of anatomic pathology automation include automation of histology protocols, barcode labeling of cassettes and cassette driven labeling of slides, auto stainers as well as interfaces to immunostaining devices. Of these the use of auto stainers for immunoperoxidase staining and special histologic stains are in widespread use as are processes that automate ordering of histology protocols. This allows for the accessioning process to drive the appropriated selection of blocks including generating appropriate billing fee codes and the automation of histology logs being sent to the histology laboratory. This increases efficiency and allows for LEAN process to be effected as well as standardized work. A critical offshoot of this type of automation are revenues are enhanced. It is critical to realize however, that
even as simple as automating the ordering of histology protocols at accession requires extensive iterative work to eliminate defects and get the most satisfactory results.

Additional examples of automation systems include robotic embedders, robotic microtomes and conveyer belt and transport systems that have been developed by BML Laboratories. BML in fact has come very close to a complete anatomic pathology automation like be linking a variety of automation technologies together with tracking, routing and transport system. There are many other robotic technologies including robotic block samplers and label capture slide samplers which have been developed and are employed widely in research. As mentioned automation of staining platforms for routine, immunoperoxidase and special stains is common place including the ability to automatically cover slip microscopic slides. A critical roadblock to widespread adoption and effective utilization of these platforms is the fact that these have not been well interfaced to the LIS, critical step to decreasing error and improving efficiency of these robots.

REFERENCES


College of American Pathologists system review series: Laboratory automation systems & workcells. CAP Today [www.CAP.org].