The Comparative Pathology Workbench:
An Integrated Online Tool for Interactive Visual Analytics for Biomedical Data

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Introduction

The Comparative Pathology Workbench (CPW) is a tool to help pathologists **gather and share related data into a single place**, with a meaningful structure for further observation and analysis. This allows for maximum flexibility and ensures that as many user styles and preferences are catered for. The CPW uses a **"spreadsheet metaphor" to allow the user to arrange data in cells in rows & columns - tabular format - called a "Workbench" or "Bench"**. This system allows for easy visualisation of any imaging data to further enhance understanding and share observations between users.

Overview

The CPW Bench Structure

- A Simple Bench in the CPW, with the Application Control Header in Blue, A Collection providing Images in Orange, and the Bench consisting of Cells in Green, Headers in Yellow and Footers in Grey.

(A) Column Header Cell – Add a title to the column; Move the column around, etc

(B) Master Cell – Edit Bench parameters;

(C) Row Header Cell – see Column Header Cell

(D) Ordinary Cell –Populate with images by "Drag'n'Drop"

(E) Row Footer Cell – Expand the Bench by "Drag'n'Drop"

(F) Column Footer Cell – See Row Footer Cell;

(G) Collection Menu – Select a different Collection of Images here

Exemplar 1. Crohn's Disease Fibrostenosing Lesion Comparative Analysis

- The CPW provides a visualisation of the differences in the morphology of a set of 30 terminal ileal fibrostenosing lesions, surgically resected from different Crohn's disease patients.
- In addition, a set of 30 normal terminal ileum controls were collected from non-Crohn's patients, in the context of the Human Gut Cell Atlas programme (https://www.ed.ac.uk/comparative-pathology/the-gut-cell-atlas-project).

(A) A Bench displaying images of the histological sections. Rows represent specific samples; columns represent specific stains and/or data related to these samples.
(B) The Chain link icons represent links that were created between images, to notify the user that there is a relationship between such sections.
(C) The Red-dashed box represents an accumulation of all data points quantified from annotations. These represent the surface area of each region of the ileum wall, as well as the collagen area, stained by PSR & quantified using QuPath. The summary data can be found in the last row as shown in "Data Summary".
(D) The CPW provides a "Bench Commentary" facility for discussion about the Bench contents to further increase the interpretation & understanding of the histochemical analyses.

https://workbench-czi-cpw.mvm.ed.ac.uk/home/

Exemplar 2. DERMATLAS Skin Tumour Expert Diagnosis Review

- The DERMATLAS (http://www.dermatlasproject.org/) project aims to collect 70 types of uncommon and rare skin tumours, with around 50 cases for each tumour type.
- A series of Benches in the CPW have been created in order to extensively review this wide range of skin tumours in a practical and pathologist-friendly way; a Bench has been created for each skin tumour type to provide easy access for histopathologists in the study.

This is a typical DERMATLAS Bench for reviewing immunohistochemistry stains.
Column headers represent the different stains used with the samples (eg. "HE", "MSH2", etc), with Row headers indicating specific cases (eg. "PD46980a" etc). This bench layout allows the individual cases to be easily reviewed, compared and discussed by different pathologists.

https://workbench-canada-cpw.mvm.ed.ac.uk/home/

Exemplar 3. Coeliac Disease Duodenal Biopsy Diagnosis Concordance Audit

- A Bench was created for a histopathological audit study of a large series of scanned whole slide images (WSI) of duodenal biopsies. These showed either normal appearances, or Coeliac disease diagnostic features, including total or subtotal villous atrophy, crypt hyperplasia, and intraepithelial lymphocytosis.

- A group of 13–17 pathologists, including expert gastrointestinal consultant histopathologists, were asked to use the CPW platform to view a series of scanned whole slide images, and make a diagnosis of either normal appearances, coeliac disease, or indeterminate/uncertain conclusion. This allowed a remote audit study to be rapidly and efficiently performed by this group of pathologists using the CPW.

- The initial round of diagnoses were made by the panel of pathologists without knowledge of any other pathologists' diagnoses or opinions.

https://workbench-coeliac-cpw.mvm.ed.ac.uk/home/

Conclusions and Future Work

Conclusions:

- The CPW enables rapid and effective histopathology analysis via a novel visual interface, coupled with sharing and discussion capabilities for widely distributed collaborative teams.

- The effectiveness has been demonstrated with two research-based exemplars, from which further publications are emerging.

- In addition, a use-case for histopathology auditing, in this instance for coeliac disease in duodenal biopsies, has been presented to illustrate the effectiveness of the approach.

Future work:

- Integration is ongoing with data from EBI's Single Cell Expression Atlas (for inclusion of references to t-SNE & UMAP plots from Single Cell RNA-seq data), histopathological images from OMERO servers, and QuPath digital pathology image analysis data.

- Furthermore, an integration will be built to reference the Human Cell Atlas Data / Helmsley Gut Cell Atlas Data Repository.

- CPW software is freely available to all as open-source software at GitHub repository https://github.com/Comparative-Pathology

Publications

"The Comparative Pathology Workbench: Interactive Visual Analytics for Biomedical Data"
Wicks MN, Glinka M, Hill B, Houghton D, Sharghi M, Ferreira I, Adams D, Din S, Papatheodorou I, Kirkwood K, Cheeseman M, Burger A, Baldock RA, and Arends MJ.
Journal of Pathology Informatics, 2023, 100328, ISSN 2153-3539, https://doi.org/10.1016/j.jpi.2023.100328.

"CD, or not CD, that is the question – a digital inter-observer agreement study in coeliac disease"
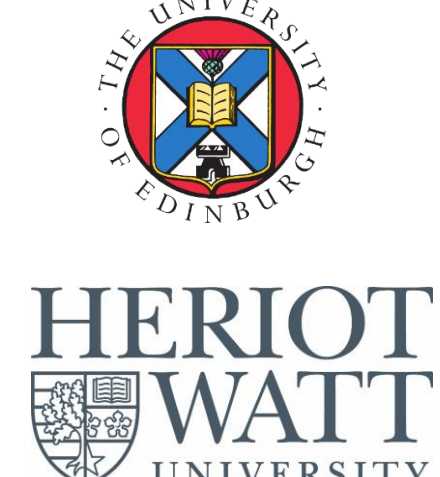Jaeckle F, Denholm J, Schreiber BA, Wicks M, Benbow E, Bracey T, Chan J, Fryer E, Gopallkrishnan K, Hughes C, Kirkwood K, Langman G, Mahler-Araujo B, McMahon R, Myint K, Natu S, Robinson A, Sanduka A, Sheppard K, Tsang Y, Arends MJ, Soilleux EJ., Histopathology 2023 (accepted for publication in *BMC Gastroenterology*).

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References: **OMERO:** http://www.openmicroscopy.org/; **EBI SCA:** https://www.ebi.ac.uk/gxa; **QuPath:** https://qupath.github.io/

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