

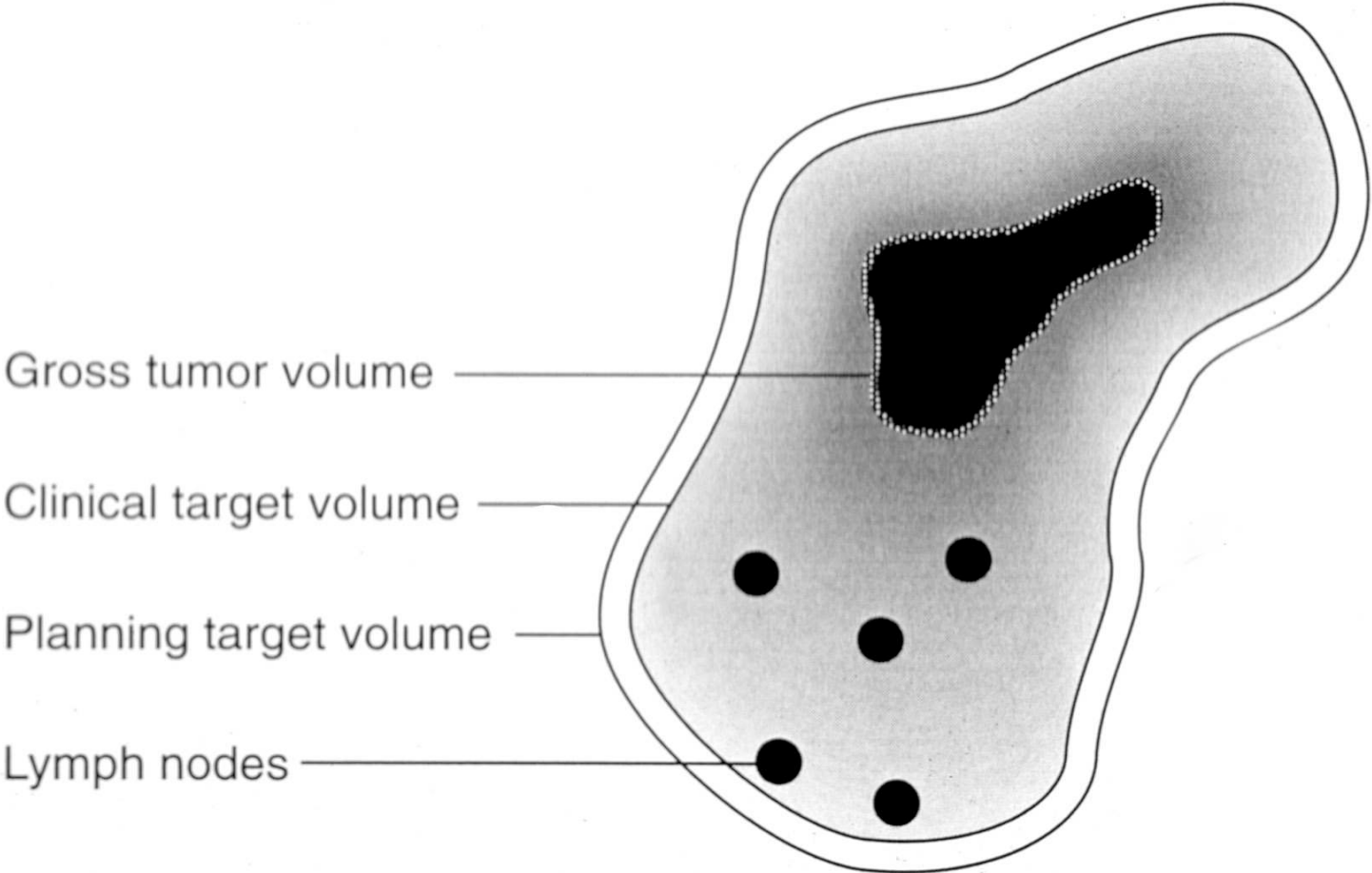
Ontologically Computing the Spread of Tumor Cells

Ira Kalet, Radiation Oncology
Noah Benson, Medical Education and Biomedical Informatics
Mark Whipple, Otolaryngology
University of Washington
Seattle, Washington USA

Other contributors:

Cornelius Rosse	Professor, Biological Structure
Jim Brinkley	Professor, Biological Structure
Matthew Lease	Computer Science and Engineering, BS, 1999
Jonn Wu	Radiation Oncology Fellow, 1999
Silvia Pessah	Biomedical and Health Informatics, MS, 2002
Jerry Barker	Radiation Oncology Resident, 2000-2002
Mary Austin-Seymour	Professor, Radiation Oncology
Mark Whipple	Assistant Professor, Otolaryngology
Noah Benson	Biomedical and Health Informatics, PhD student
Linda Shapiro	Professor, Computer Science and Engineering
Chia-Chi Teng	Electrical Engineering, PhD student

Defining the GTV, CTV and PTV



Anatomic Knowledge from the UW FMA Server

```
> telnet fma.biostr.washington.edu 8098
Trying 128.95.10.191...
Connected to fma.biostr.washington.edu (128.95.10.191).
Escape character is '^]'.
connected
3
(fms-get-children "Heart" "part")
received
4
( "Coronary sinus" "Great cardiac vein" "Left marginal vein"
  "Posterior vein of left ventricle" "Middle cardiac vein"
  "Small cardiac vein" "Oblique vein of left atrium"
  "Right marginal vein" "Right atrium" "Left atrium"
  "Right ventricle" "Left ventricle" "Interatrial septum"
  "Interventricular septum" "Atrioventricular septum"
  "Right side of heart" "Left side of heart" "Tricuspid valve"
  "Mitral valve" "Aortic valve" "Pulmonary valve" "Wall of heart"
  "Cavity of right ventricle" "Cavity of left atrium"
  "Cavity of left ventricle" "Fibrous skeleton of heart"
  "Cavity of right atrium" "Papillary muscle"
  "Right coronary artery" "Left coronary artery"
  "Anterior interventricular vein" "Systemic capillary bed of heart"
  "Lymphatic capillary bed of heart" "Basal zone of heart"
  "Mid zone of heart" "Apical zone of heart" )
3
```

Recursive Queries on the FMS

```
(defun lymphatic-drainage (stream term)
  (get-children stream term "lymphatic drainage"))
```

```
(defun all-paths (paths next-nodes stream)
```

```
"ALL-PATHS paths next-nodes stream
```

searches a finite directed acyclic graph and returns all paths starting with each path in paths. A path is a list of nodes, paths is a list of paths, and next-nodes is a function that generates the descendant nodes from any given node. The paths are extended using cons so they are each in reverse order from final to initial node."

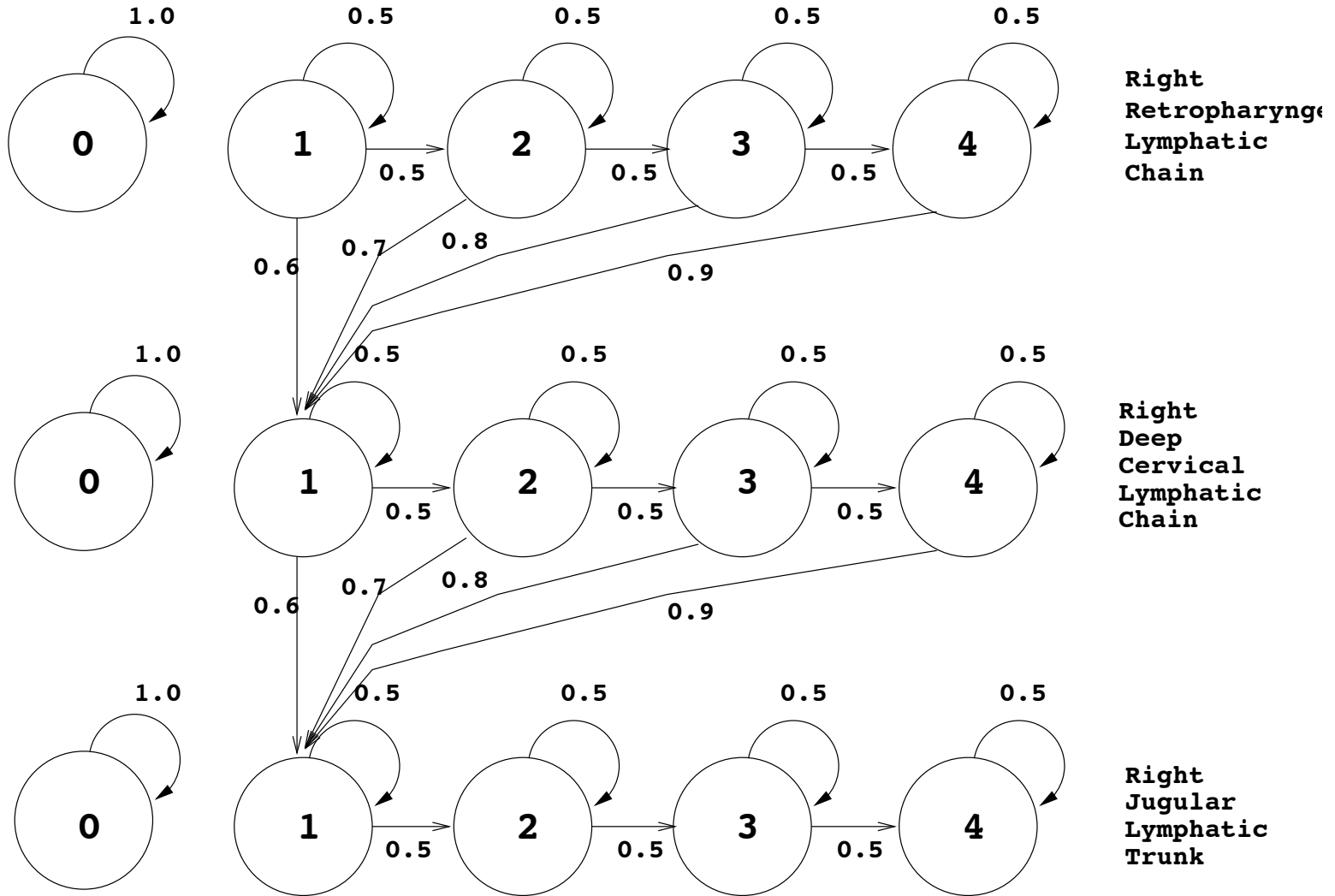
```
(apply #'append
  (mapcar #'(lambda (path)
    ;; for each path, either
    (let ((nexts (funcall next-nodes
                          stream (first path))))
      (if nexts ;; return a list of extended paths
          (all-paths (mapcar #'(lambda (node)
                                (cons node path))
                          nexts)
                      next-nodes stream)
          (list path)))) ;; or just return it
    paths)))
```

Paths for the Soft Palate

```
CL-USER(3): (nodes fms "Soft palate")
LYMPHATIC DRAINAGE OF "Soft palate":
("Superior deep lateral cervical lymphatic chain"
 "Right retropharyngeal lymphatic chain"
 "Left retropharyngeal lymphatic chain")

("Soft palate" LYMPHATIC-DRAINAGE
 ("Superior deep lateral cervical lymphatic chain"
  "Jugular lymphatic chain" "Jugular lymphatic trunk")
 ("Superior deep lateral cervical lymphatic chain"
  "Inferior deep lateral cervical lymphatic chain"
  "Jugular lymphatic trunk")
 ("Right retropharyngeal lymphatic chain"
  "Right deep cervical lymphatic chain"
  "Right jugular lymphatic trunk"
  "Right lymphatic duct")
 (...))
```

A Markov Model for Metastasis



Results, Conclusions and Future Work

- A metastasis predictor based on lymphatic topology looks promising as a useful theory
- Refining the Markov model will require more surgical data
- Extending the model to other tumor classes (e.g. breast cancer) simply requires continuing to populate the FMA
- Automated generation of the target volume needs somewhat better image mapping (in progress)
- Finer granularity in defining target volumes may be possible

Thanks

- to everyone mentioned earlier,
- the National Cancer Institute for grant support for Radiotherapy Treatment Planning Tools software projects
- the National Library of Medicine for grant support for the FMA, Prism, Biomedical Informatics Research Training and a Publication Grant for my forthcoming book, “Principles of Biomedical Informatics”
- to Larry Hunter for hospitality, advice and enthusiasm, and
- to John McCarthy for inventing Lisp.