"A collaborative project to
develop a universal framework for
encoding and disseminating electronic clinical guidelines"

The SAGE Project

Standards-Based Sharable Active Guideline Environment

"A collaborative project to develop a universal framework for sharing health knowledge in the form of computable clinical practice guidelines"

Partnerships In Innovation

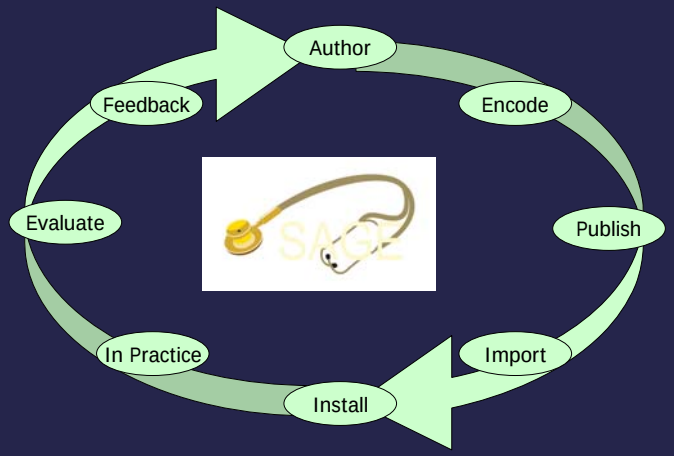
13 November 2006

AMIA 2006 Washington, DC

Introduction and Overview

- SAGE Project Goals and Vision
- SAGE Project Approach and Architecture

Guy Mansfield, Ph.D.
GE Healthcare



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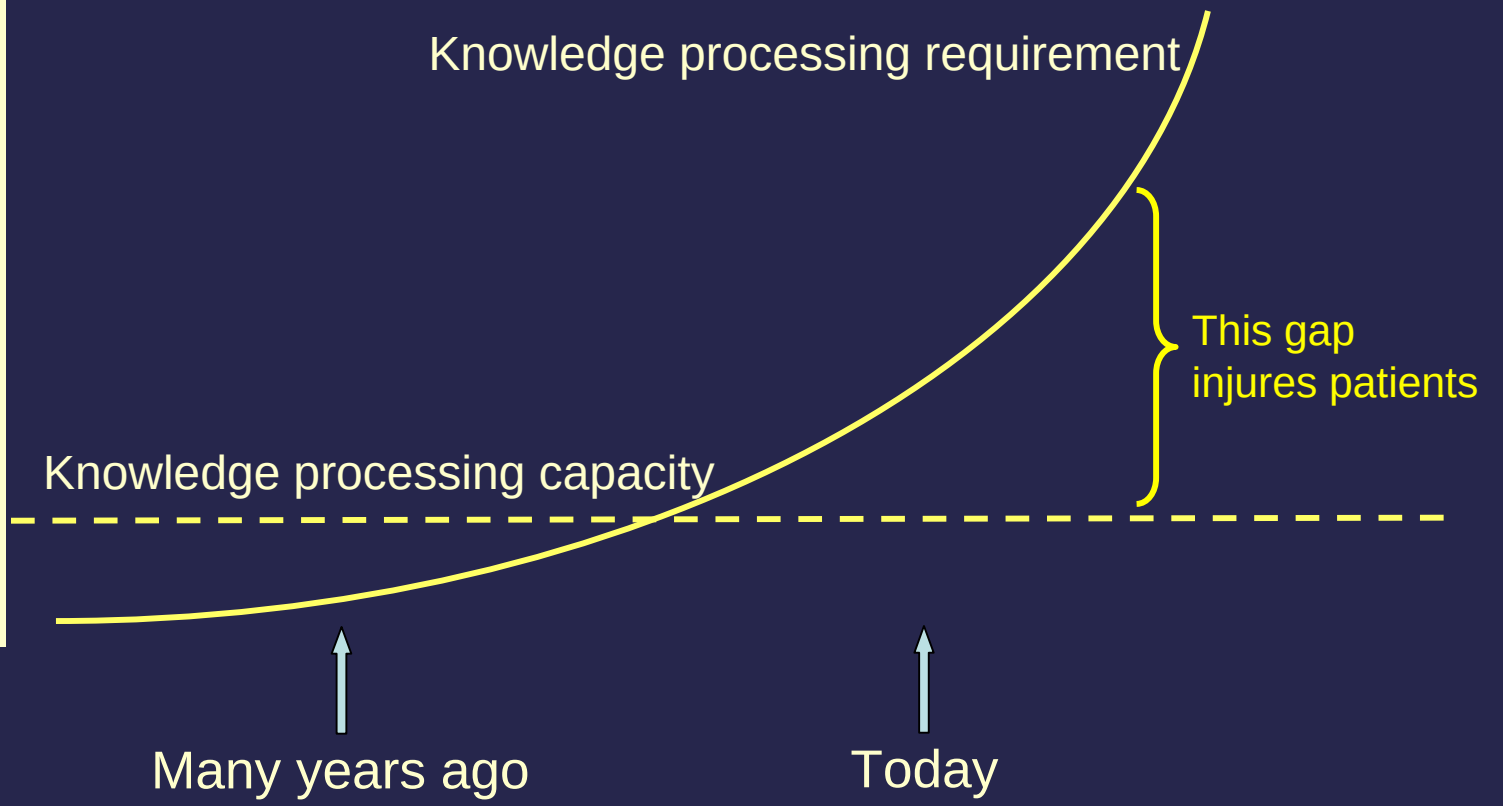
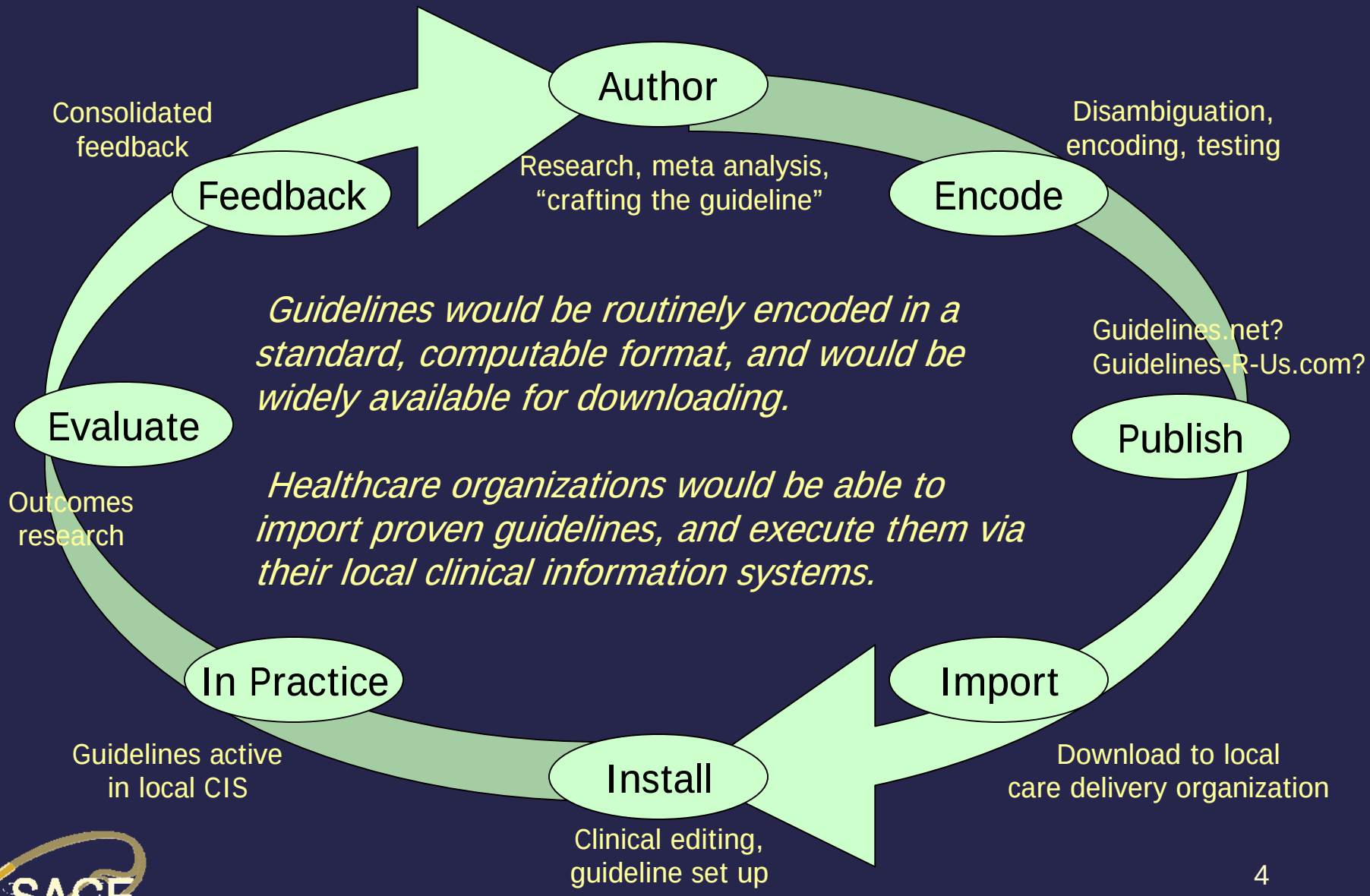
The Clinical Knowledge-Processing Burden

"Current medical practice relies heavily on the unaided mind to recall a great amount of detailed knowledge – a process which, to the detriment of all stakeholders, has repeatedly been shown unreliable"

Crane and Raymond
The Permanente Journal
Winter 2003 Volume 7 No.1
Kaiser Permanente Institute for Health Policy



The SAGE Guideline Lifecycle Vision



Guidelines would be routinely encoded in a standard, computable format, and would be widely available for downloading.

Healthcare organizations would be able to import proven guidelines, and execute them via their local clinical information systems.

SAGE

The SAGE Project Partnership

IDX (GE Healthcare)

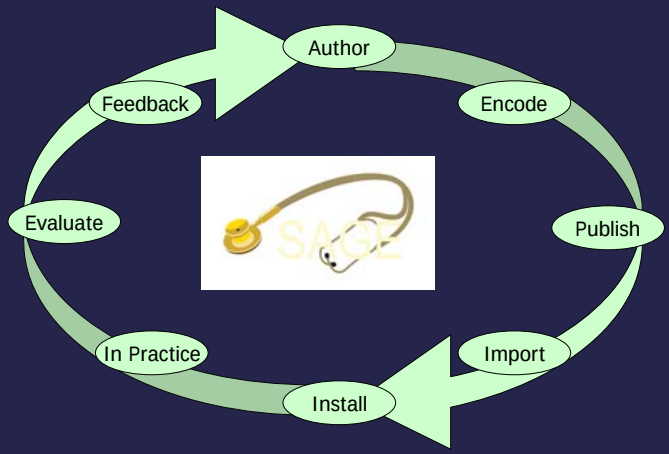
Apelon Inc.

Intermountain Health Care

Mayo Clinic Rochester

Stanford University Medical Informatics

University of Nebraska Medical Center



The SAGE Interoperability Vision

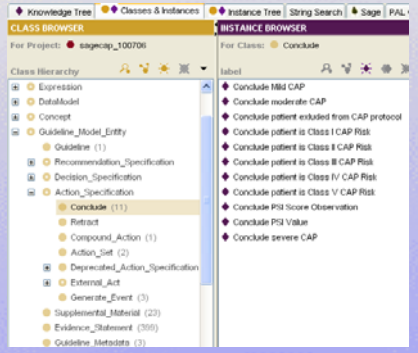
A technology infrastructure that supports:

- Clinical practice guidelines – encoded in a computable, standards-based representation.
- Once encoded, guideline content can be deployed to multiple different clinical information system platforms.
- Surfacing guideline content via functions and user interface native to the local CIS.
- Allows health care institutions to share guideline content and knowledge bases

Overview of SAGE Infrastructure

Clinical Practice Guidelines

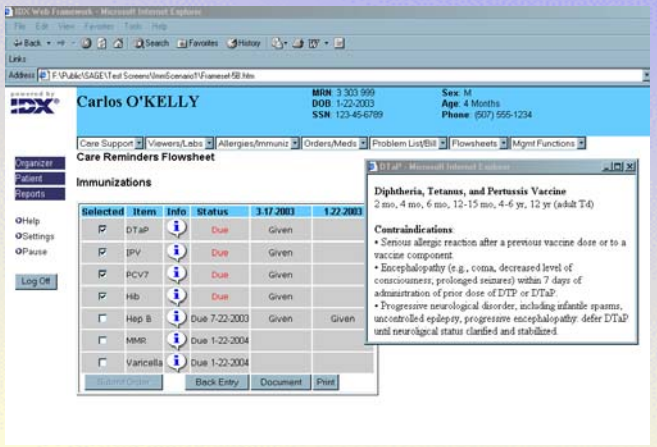
Controlled Resources



SAGE Guideline Model

Guideline Encoding

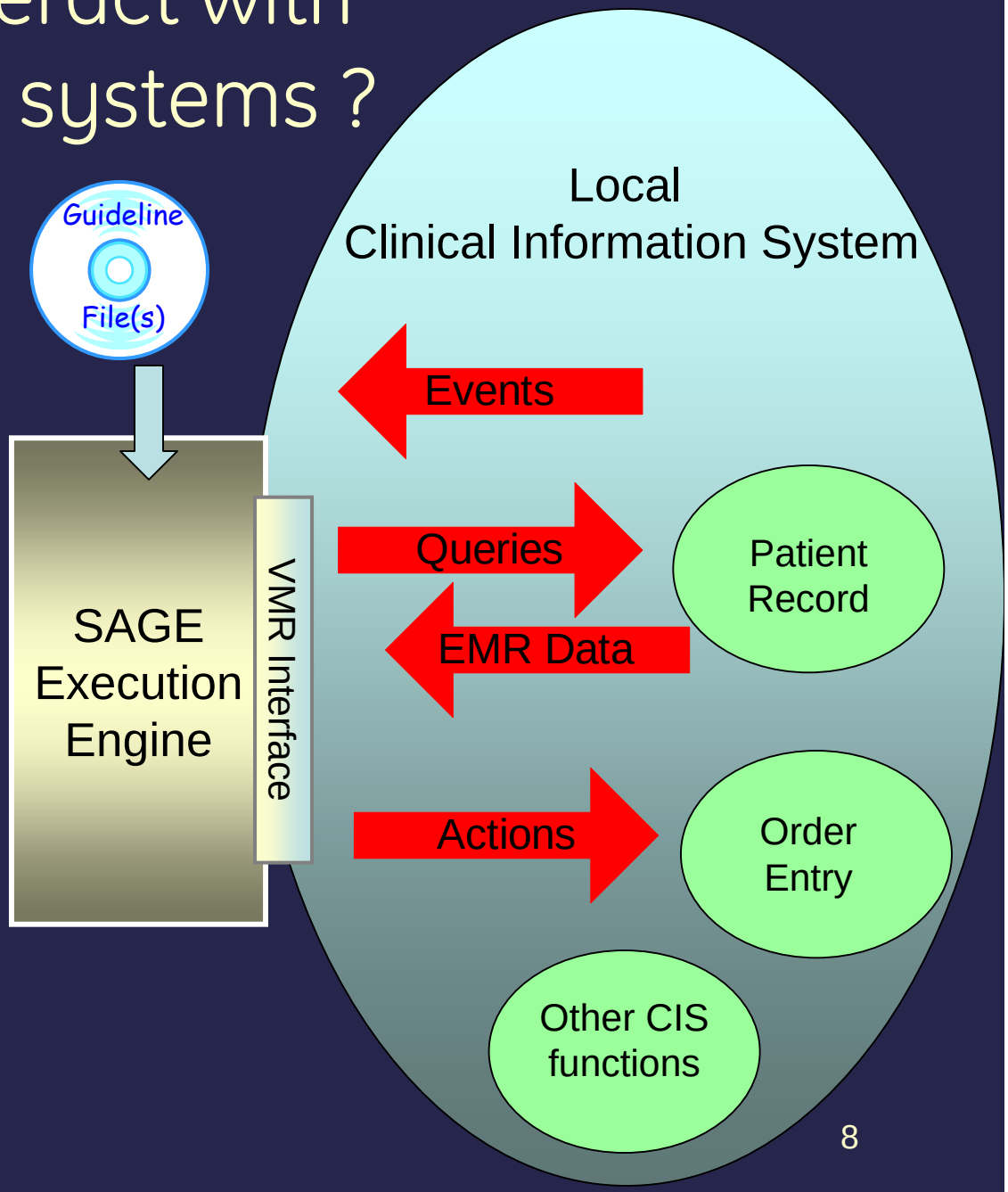
The SAGE Engine



Host Clinical Information System

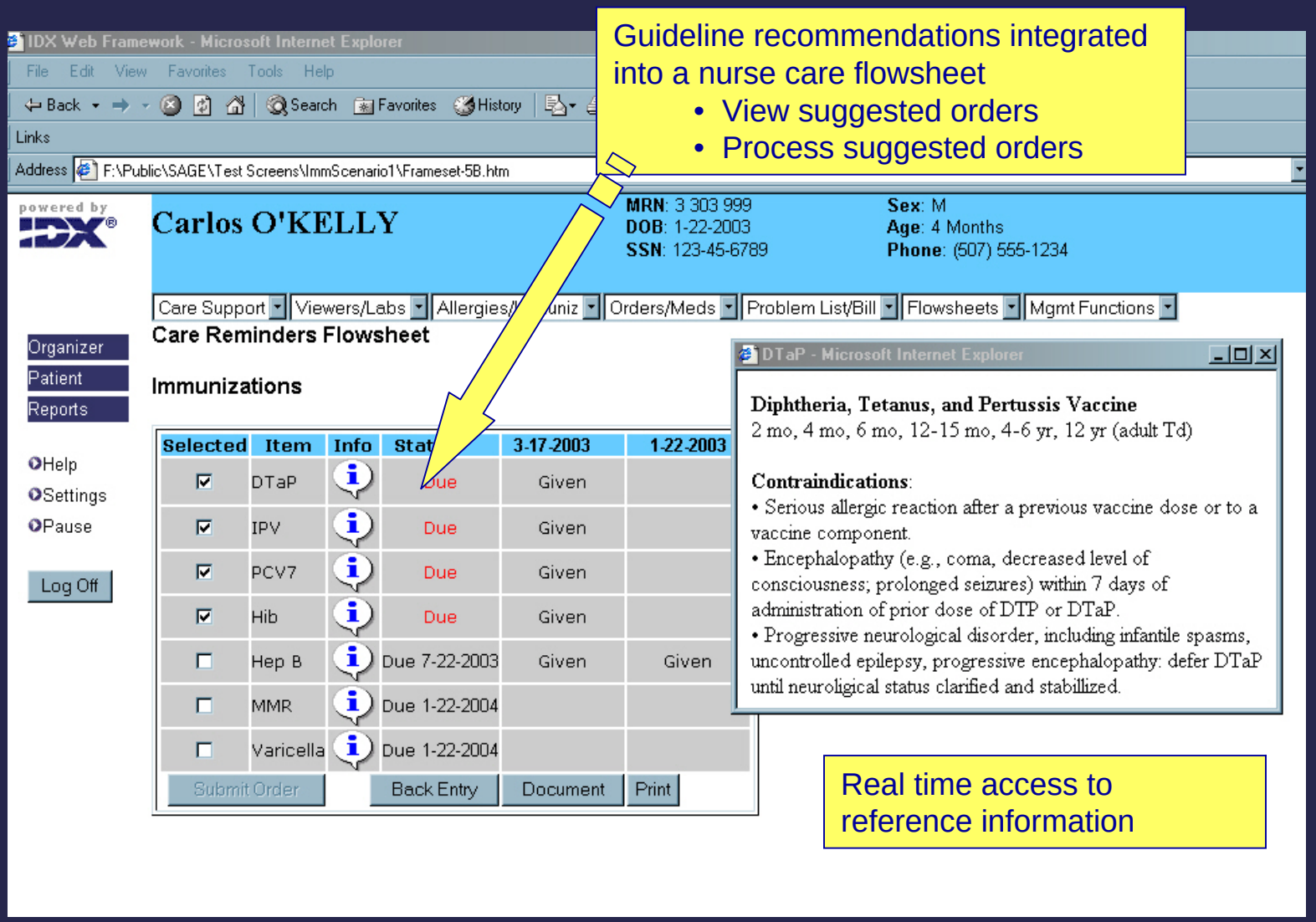
How does SAGE interact with clinical information systems ?

- It communicates with CIS via standards-based interfaces
- It detects events in the clinical workflow (e.g. patient is admitted)
- It queries data from the CIS electronic medical record (e.g. age)
- It executes guideline logic based on patient-specific data (e.g. if [K^+] > 6.0, then…)
- It makes real-time, patient-specific recommendations via functions of the local CIS (e.g., order immunization)



SAGE

“Activating Guideline Content”



Guideline recommendations integrated into a nurse care flowsheet

- View suggested orders
- Process suggested orders

Real time access to reference information

SAGE Exemplar Guidelines

Guideline	Clinical Domain
Immunizations	Routine health maintenance for all ages. In both outpatient and inpatient settings, including population surveillance.
Diabetes Mellitus	Chronic disease monitoring and treatment. Acute exacerbation of chronic disease. Medication management (for hypertension). Chronic disease as a co-morbidity.
Community Acquired Pneumonia	Emergency room evaluation and diagnosis. Outpatient, Inpatient and ICU treatment. Discharge readiness. Follow-up of acute disease.

SAGE Prototyping Cycles Drive Requirements and Prototyping

Immunizations

Diabetes Management

Community Acquired Pneumonia

What is required to represent guideline knowledge?

Guideline Representation Model

What is required to author / encode the guideline contents?

Guideline Encoding Workbench

What is required to decode the guideline and interact with a CIS?

Guideline Deployment System

- Guideline Engine
- VMR interface
- Other components

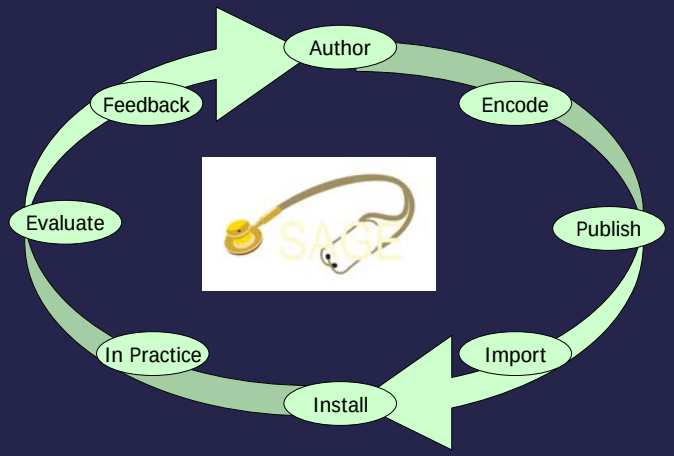
What controlled resources and information models are required?

Controlled Resources

The SAGE Guideline Model

- Representing Guideline Knowledge
- SAGE Guideline Encoding Tools

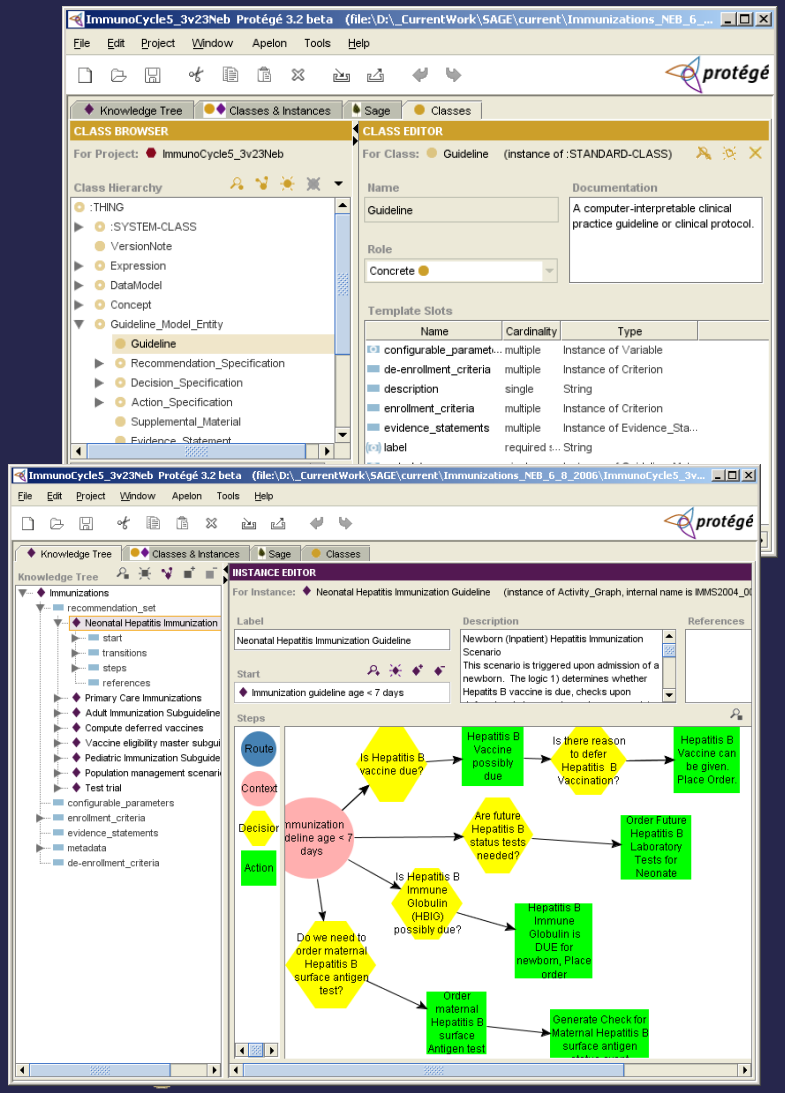
Mark A. Musen, MD, Ph.D.
Samson W Tu, MS
Ravi D. Shankar, MS
Stanford Medical Informatics



SAGE Guideline Model and Encoding Tools

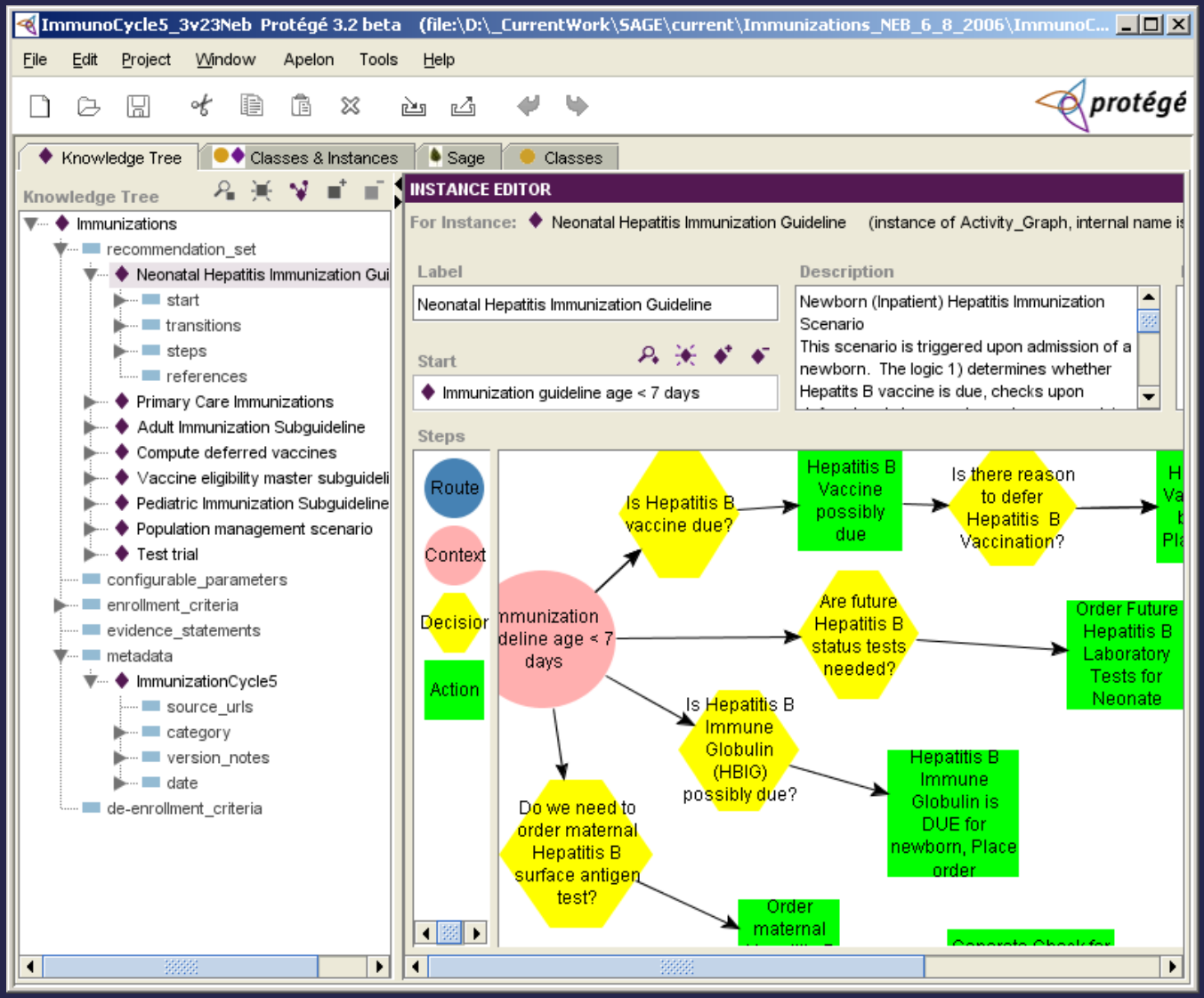
- Builds on prior work with guideline representation
- Highlights
  - Multi-faceted knowledge representation
  - Extensive support for guideline encoding

SAGE Guideline Model and Modeling Environment

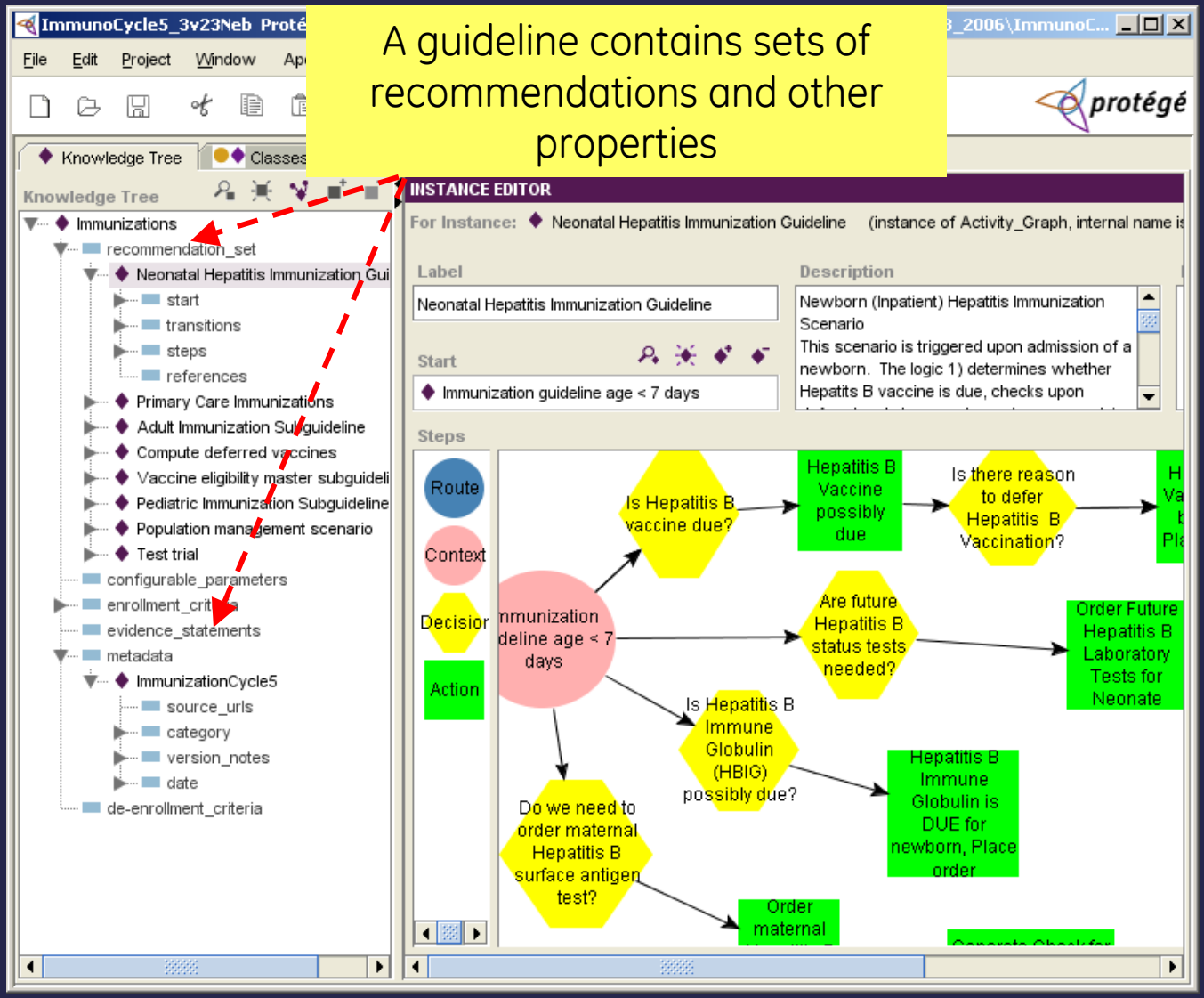


- Guideline model and instances created in Protégé
- Guideline model represented as a collection of classes and relationships among them
- Encoding a guideline (e.g. immunization guideline) means creating instances of these classes
- Protégé provides tool to specify guideline recommendations as directed graphs

Guideline Representation: Recommendation Sets



Guideline Representation: Recommendation Sets



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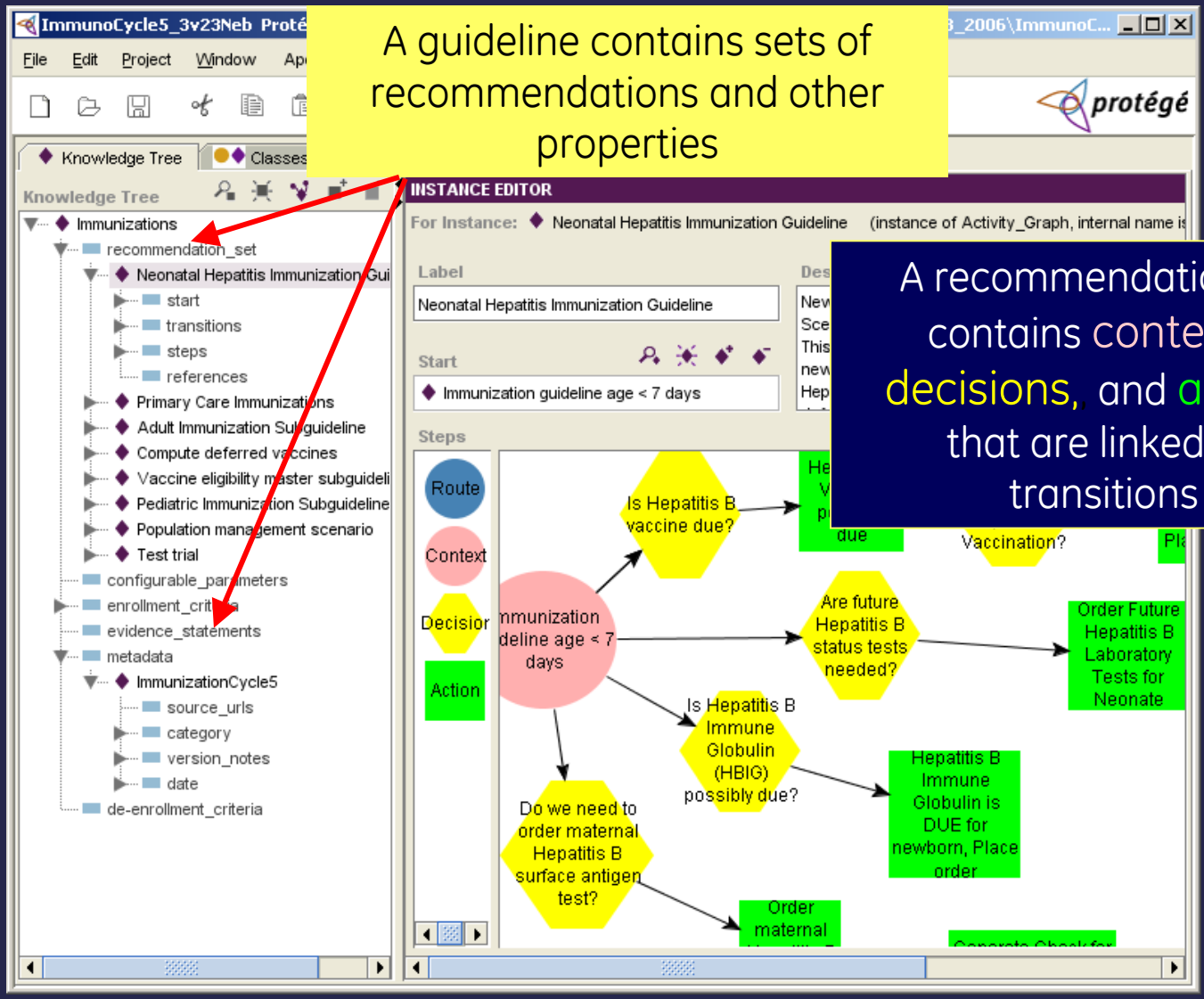
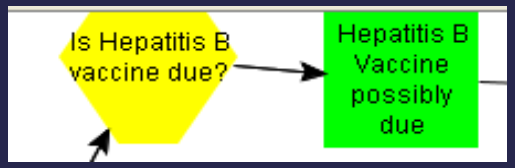


A Decision Node contains a decision model: reasons for choosing each alternative



Is Hepatitis B vaccine due? (instance of Decision, internal name is IMMS2...

Label: Is Hepatitis B vaccine due?

Triggering Even

Scheduling Constraint

Decision Model (1 values

Alternatives: Hepatitis B Vaccine possibly due

Subguideline

Transition R: AND join A

Automation: automatic

Hepatitis B Vaccine possibly due (instance of Alternative_Choice, internal...

Alternative: Hepatitis B Vaccine possibly due

Recommendation Threshhold: 1

Strict Rule Out: Patient received Hep B or has current order

Strict Rule In: Mother is HBsAg POSITIVE OR (HBsAg unkno; Weight (of baby) >= 2 kg

Rule Out

Rule In

SAGE

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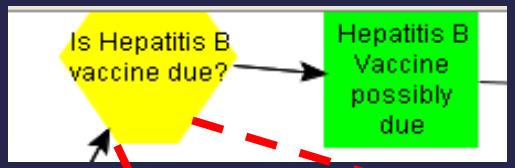

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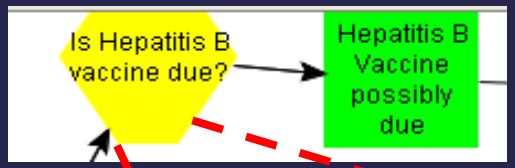

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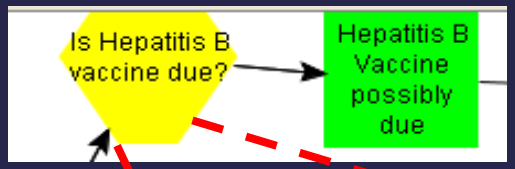

Rule-in and rule-out criteria determines whether an alternative is recommended

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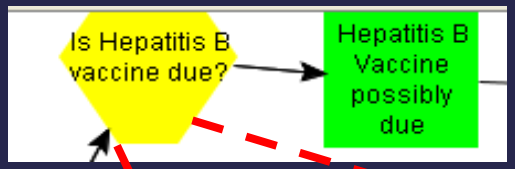

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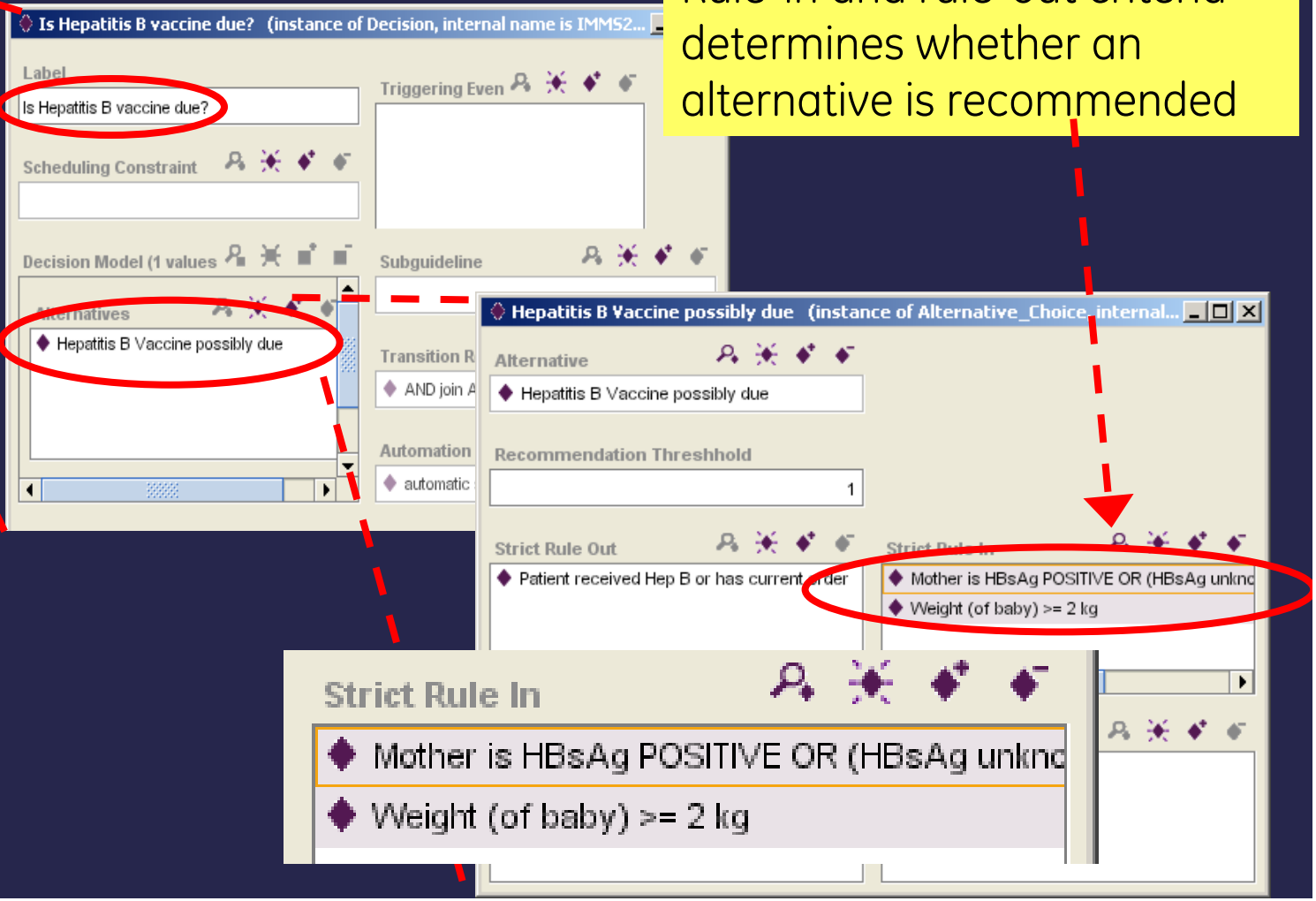
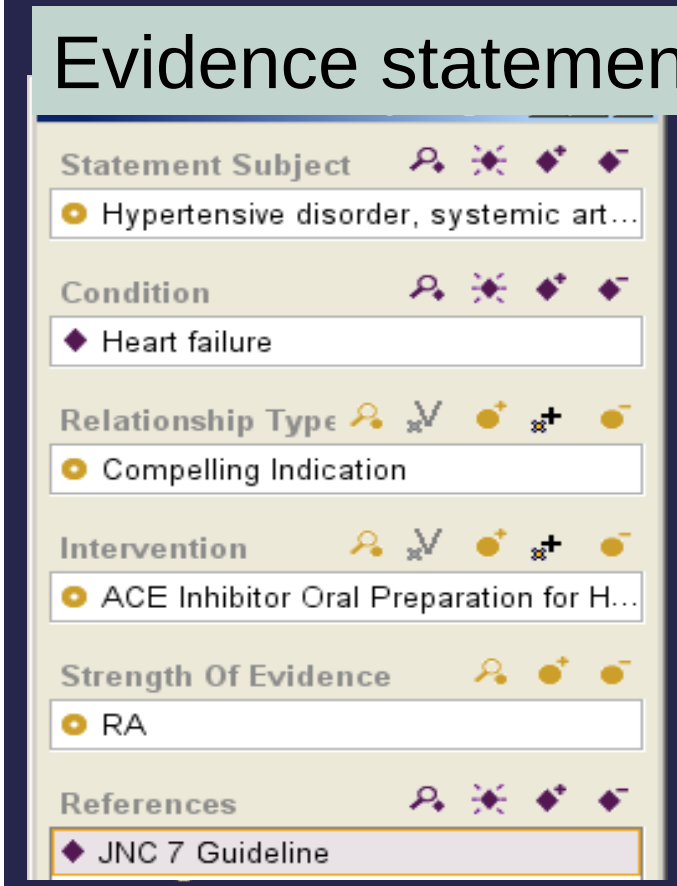


SAGE

Guideline Representation: Evidence Statement

JNC 7 Report: In the management of hypertension, heart failure is a compelling indication for the use of ACE inhibitor; strength of evidence RA (based on trial evidence).



- Decision support query

  If patient has a condition that is a compelling indication for the use of ACE inhibitor, then …

- Decision support engine evaluates collection of evidence statements

Tu, S. W., Hrabak, K. M., et al. Use of Declarative Statements in Creating and Maintaining Computer-Interpretable Knowledge Bases for Guideline-Based Care. AMIA 2006,.Session 26

Guideline Representation: External Knowledge Source

How can knowledge in an external source be accessed?
e.g., “What is the maximum daily dose of atenolol oral preparation for hypertension?”

- Virtual Knowledge Base
  - Simplified information model of external knowledge source
  - Query knowledge source based on simplified view
- Example: Drug knowledge source class ‘Active Ingredient Preparation’
  - Query max_daily_dose of Active Ingredient Preparation where code is atenolol
  - Decision support engine resolves query in terms of query to external knowledge source

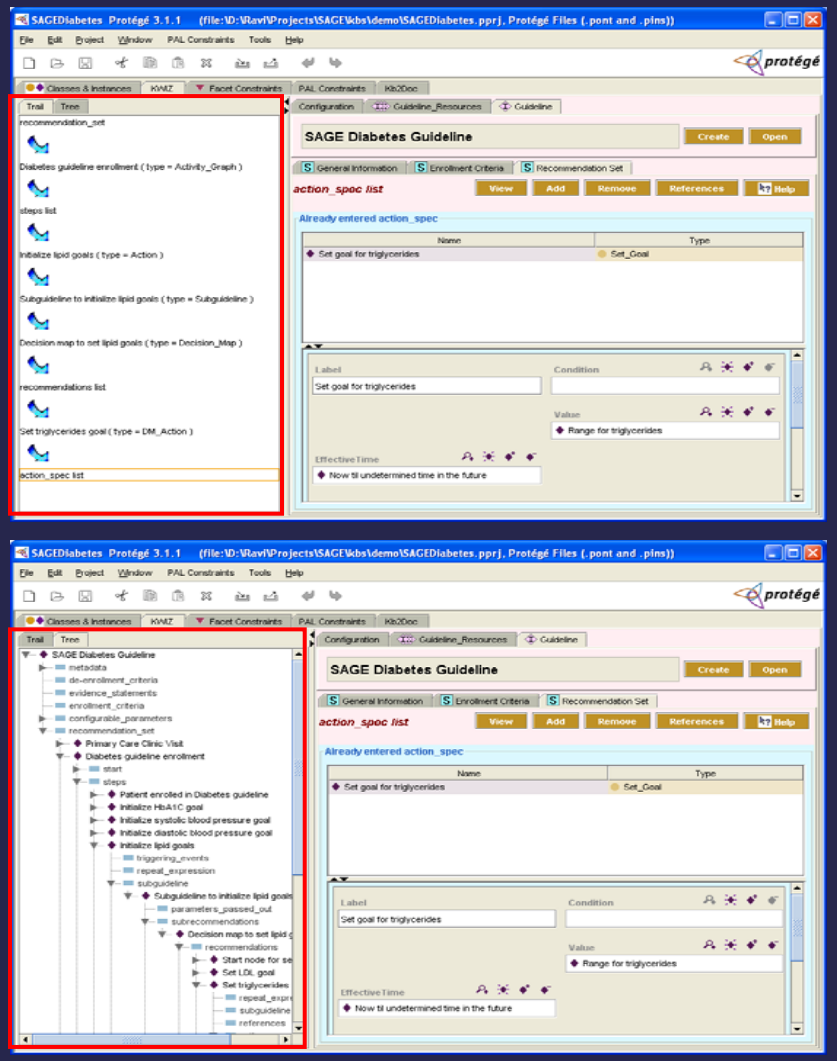
SAGE Guideline Workbench

- Based on Protégé
- Extensions
  - Alternative instance form: KWIZ tab
  - Generation of XML/HTML: kb2doc tab
  - Case-based testing: SAGE tab
  - Terminology server: Apelon terminology plugin

Discussed elsewhere

Kwiz Tab

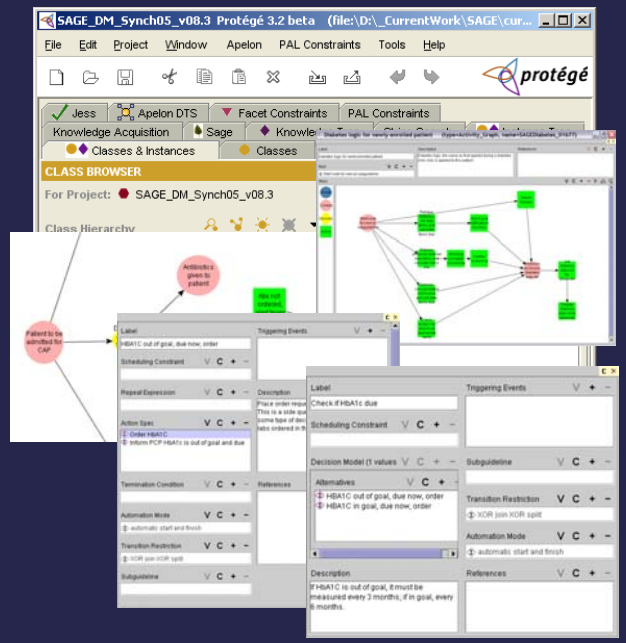
- Alternative navigation
- Enhanced Search
- Re-use of instances from libraries of pre-encoded components



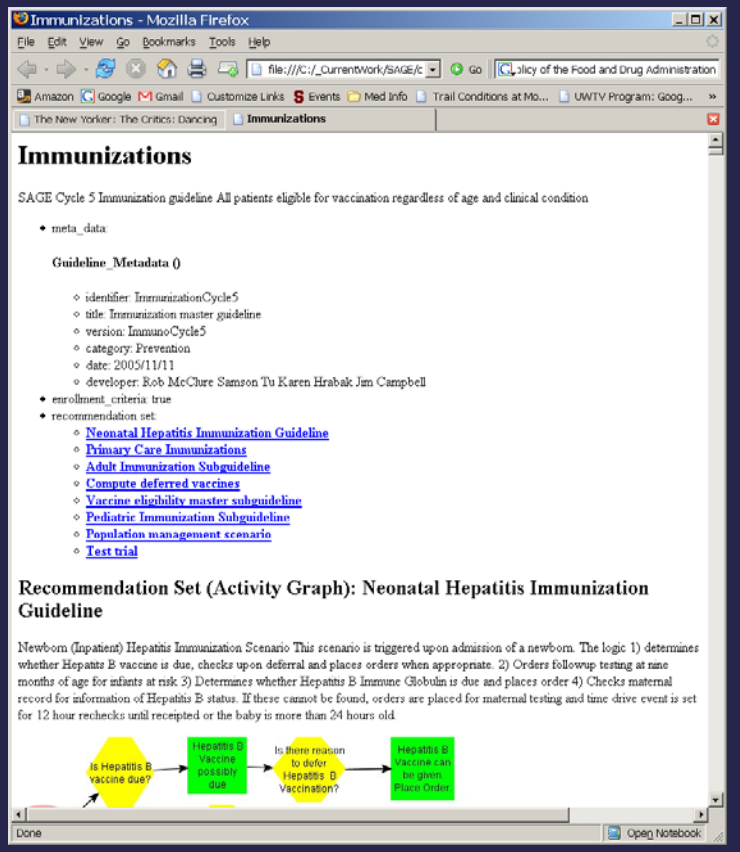
Navigation Trail and Tree

Document-Oriented View of Encoded Guideline

- Transform a complex guideline knowledge to a readable document
- Allow clinicians to review knowledge base content



XML export
XSLT style sheet



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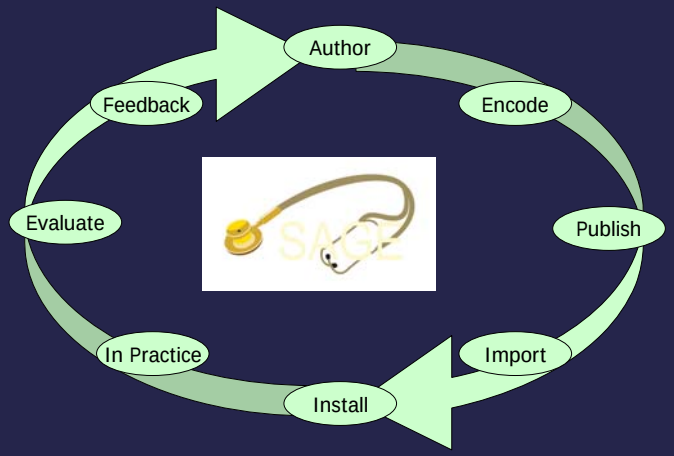
The Process of Guideline Encoding

- Collaborative development of the encoding process
- Use of standard terminologies and models

James R Campbell, MD
University of Nebraska Medical Center



SAGE Guideline Encoding Process

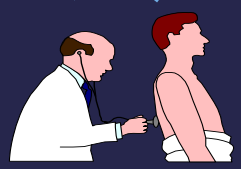
1. Assemble Source Guidelines

3. Formalize Guideline Logic

5. Formalize Vocabulary Inventory

4. Define Guideline Concepts

6. Clarify Data Representation



2. Envision Clinical Scenarios

Guideline Installation and Execution

7. Encode Guideline Knowledgebase

SAGE

2006 ADA Guideline

POSITION STATEMENT

Standards of Medical Care in Diabetes–2006

American Diabetes Association

CONTENTS

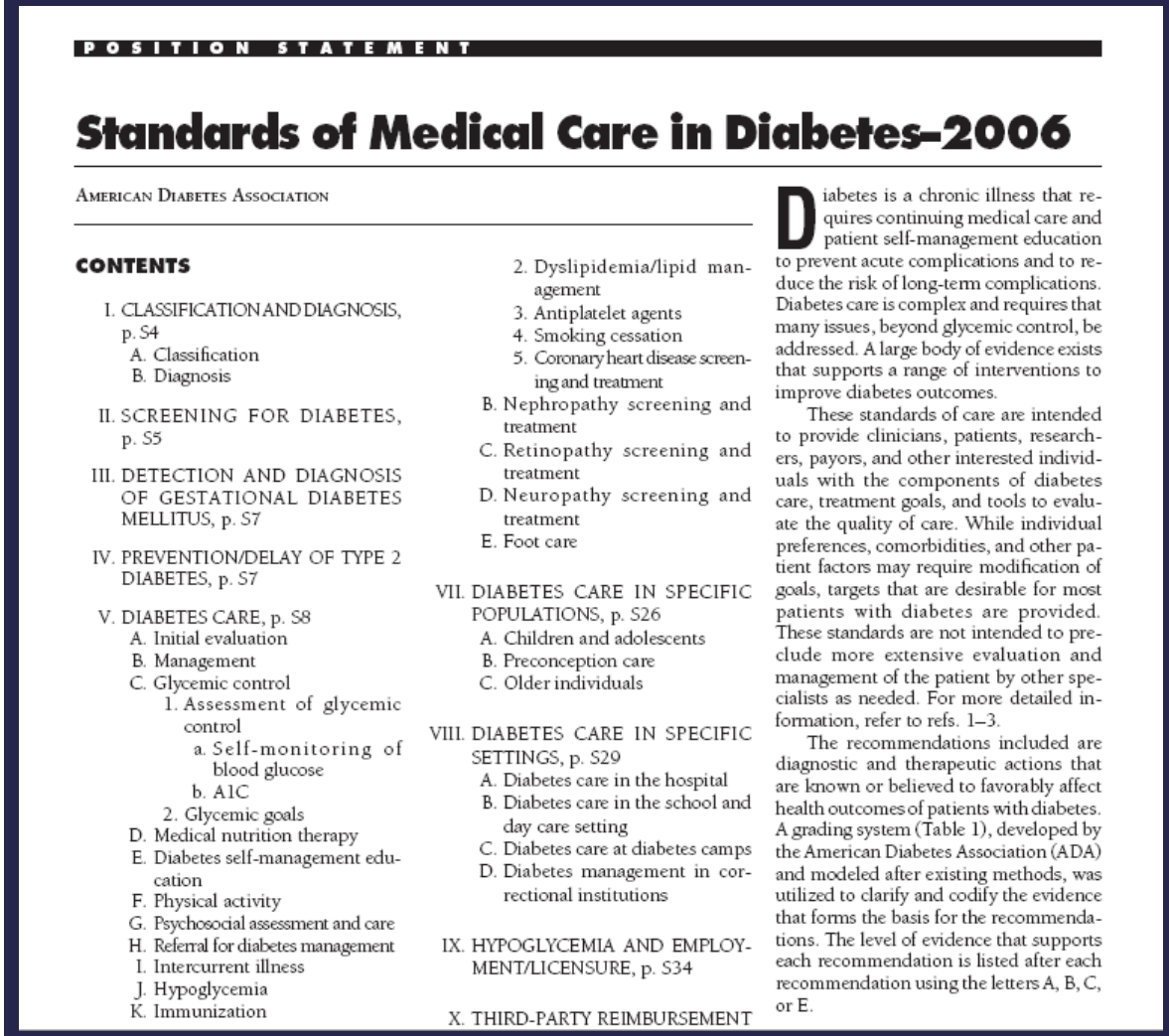
Diabetes is a chronic illness that requires continuing medical care and patient self-management education to prevent acute complications and to reduce the risk of long-term complications. Diabetes care is complex and requires that many issues, beyond glycemic control, be addressed. A large body of evidence exists that supports a range of interventions to improve diabetes outcomes.

These standards of care are intended to provide clinicians, patients, researchers, payors, and other interested individuals with the components of diabetes care, treatment goals, and tools to evaluate the quality of care. While individual preferences, comorbidities, and other patient factors may require modification of goals, targets that are desirable for most patients with diabetes are provided. These standards are not intended to preclude more extensive evaluation and management of the patient by other specialists as needed. For more detailed information, refer to refs. 1–3.

The recommendations included are diagnostic and therapeutic actions that are known or believed to favorably affect health outcomes of patients with diabetes. A grading system (Table 1), developed by the American Diabetes Association (ADA) and modeled after existing methods, was utilized to clarify and codify the evidence that forms the basis for the recommendations. The level of evidence that supports each recommendation is listed after each recommendation using the letters A, B, C, or E.

- Comprehensive care guideline from American Diabetes Association

2006 ADA Guideline



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- Standards for glycemic management

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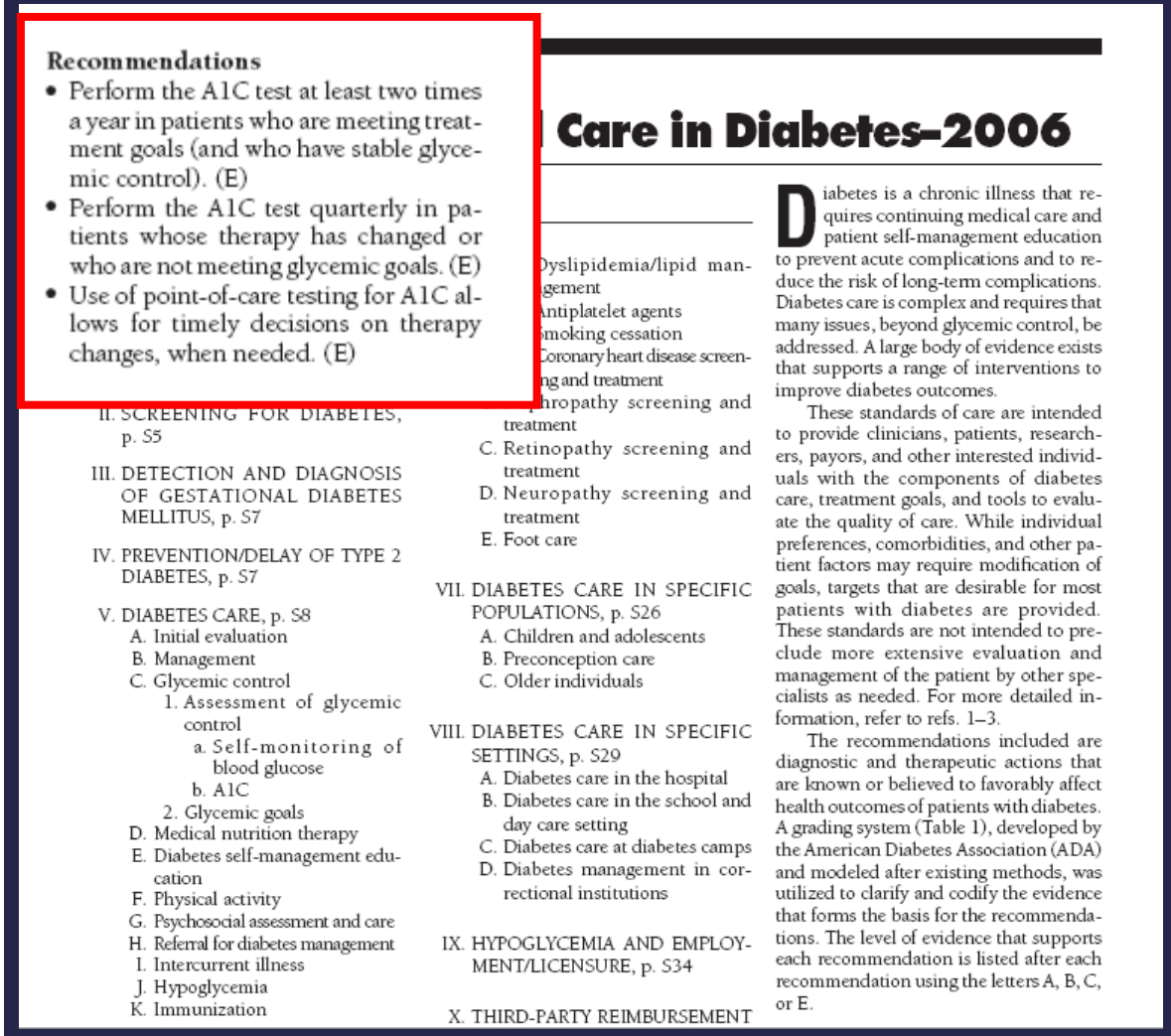

Recommendations

- Perform the A1C test at least two times a year in patients who are meeting treatment goals (and who have stable glycemic control). (E)
- Perform the A1C test quarterly in patients whose therapy has changed or who are not meeting glycemic goals. (E)
- Use of point-of-care testing for A1C allows for timely decisions on therapy changes, when needed. (E)

II. SCREENING FOR DIABETES, p. S5

III. DETECTION AND DIAGNOSIS OF GESTATIONAL DIABETES MELLITUS, p. S7

IV. PREVENTION/DELAY OF TYPE 2 DIABETES, p. S7

V. DIABETES CARE, p. S8
- A. Initial evaluation
- B. Management
- C. Glycemic control
  1. Assessment of glycemic control
     - a. Self-monitoring of blood glucose
     - b. A1C
  2. Glycemic goals
- D. Medical nutrition therapy
- E. Diabetes self-management education
- F. Physical activity
- G. Psychosocial assessment and care
- H. Referral for diabetes management
- I. Intercurrent illness
- J. Hypoglycemia
- K. Immunization

Care in Diabetes–2006

Dyslipidemia/lipid management
Antiplatelet agents
Smoking cessation
Coronary heart disease screening and treatment
Nephropathy screening and treatment
C. Retinopathy screening and treatment
D. Neuropathy screening and treatment
E. Foot care

VII. DIABETES CARE IN SPECIFIC POPULATIONS, p. S26
- A. Children and adolescents
- B. Preconception care
- C. Older individuals

VIII. DIABETES CARE IN SPECIFIC SETTINGS, p. S29
- A. Diabetes care in the hospital
- B. Diabetes care in the school and day care setting
- C. Diabetes care at diabetes camps
- D. Diabetes management in correctional institutions

IX. HYPOGLYCEMIA AND EMPLOYMENT/LICENSURE, p. S34

X. THIRD-PARTY REIMBURSEMENT

Diabetes is a chronic illness that requires continuing medical care and patient self-management education to prevent acute complications and to reduce the risk of long-term complications. Diabetes care is complex and requires that many issues, beyond glycemic control, be addressed. A large body of evidence exists that supports a range of interventions to improve diabetes outcomes.

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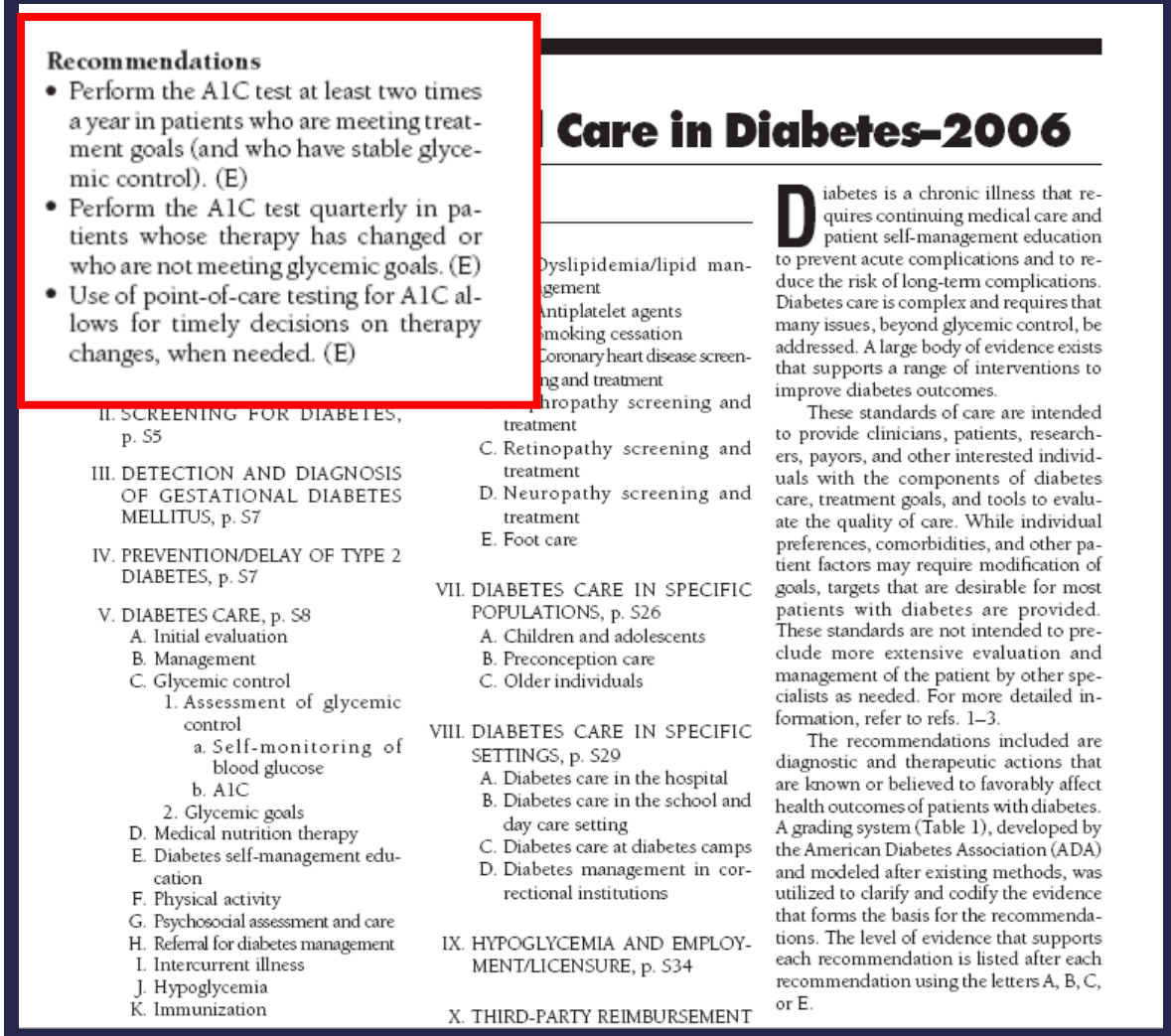

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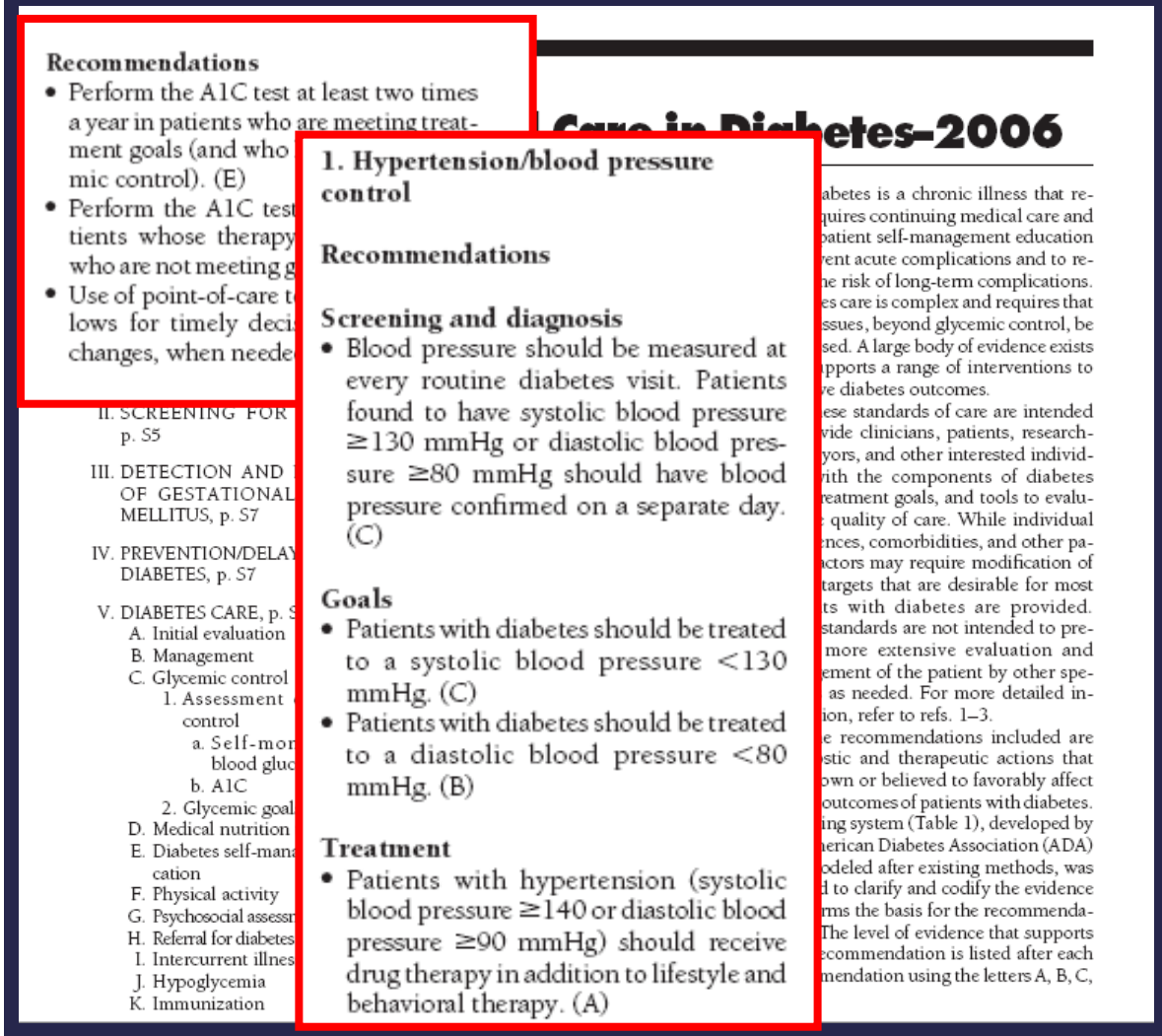
These standards of care are intended to provide clinicians, patients, researchers, payors, and other interested individuals with the components of diabetes care, treatment goals, and tools to evaluate the quality of care. While individual preferences, comorbidities, and other patient factors may require modification of goals, targets that are desirable for most patients with diabetes are provided. These standards are not intended to preclude more extensive evaluation and management of the patient by other specialists as needed. For more detailed information, refer to refs. 1–3.

The recommendations included are diagnostic and therapeutic actions that are known or believed to favorably affect health outcomes of patients with diabetes. A grading system (Table 1), developed by the American Diabetes Association (ADA) and modeled after existing methods, was utilized to clarify and codify the evidence that forms the basis for the recommendations. The level of evidence that supports each recommendation is listed after each recommendation using the letters A, B, C, or E.

- Comprehensive care guideline from American Diabetes Association
- Standards for glycemic management
- Goals for hypertension identification and treatment specialized

2006 ADA Guideline



Recommendations

- Perform the A1C test at least two times a year in patients who are meeting treatment goals (and who
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- Perform the A1C test
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- Use of point-of-care t
lows for timely deci
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II. SCREENING FOR
p. S5

III. DETECTION AND
OF GESTATIONAL
MELLITUS, p. S7

IV. PREVENTION/DELAY
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V. DIABETES CARE, p. S
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B. Management
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1. Assessment
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2. Glycemic goal
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F. Physical activity
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H. Referral for diabetes
I. Intercurrent illnes
J. Hypoglycemia
K. Immunization

1. Hypertension/blood pressure control

Recommendations

Screening and diagnosis

- Blood pressure should be measured at every routine diabetes visit. Patients found to have systolic blood pressure ≥130 mmHg or diastolic blood pressure ≥80 mmHg should have blood pressure confirmed on a separate day. (C)

Goals

- Patients with diabetes should be treated to a systolic blood pressure <130 mmHg. (C)
- Patients with diabetes should be treated to a diastolic blood pressure <80 mmHg. (B)

Treatment

- Patients with hypertension (systolic blood pressure ≥140 or diastolic blood pressure ≥90 mmHg) should receive drug therapy in addition to lifestyle and behavioral therapy. (A)

Care in Diabetes–2006

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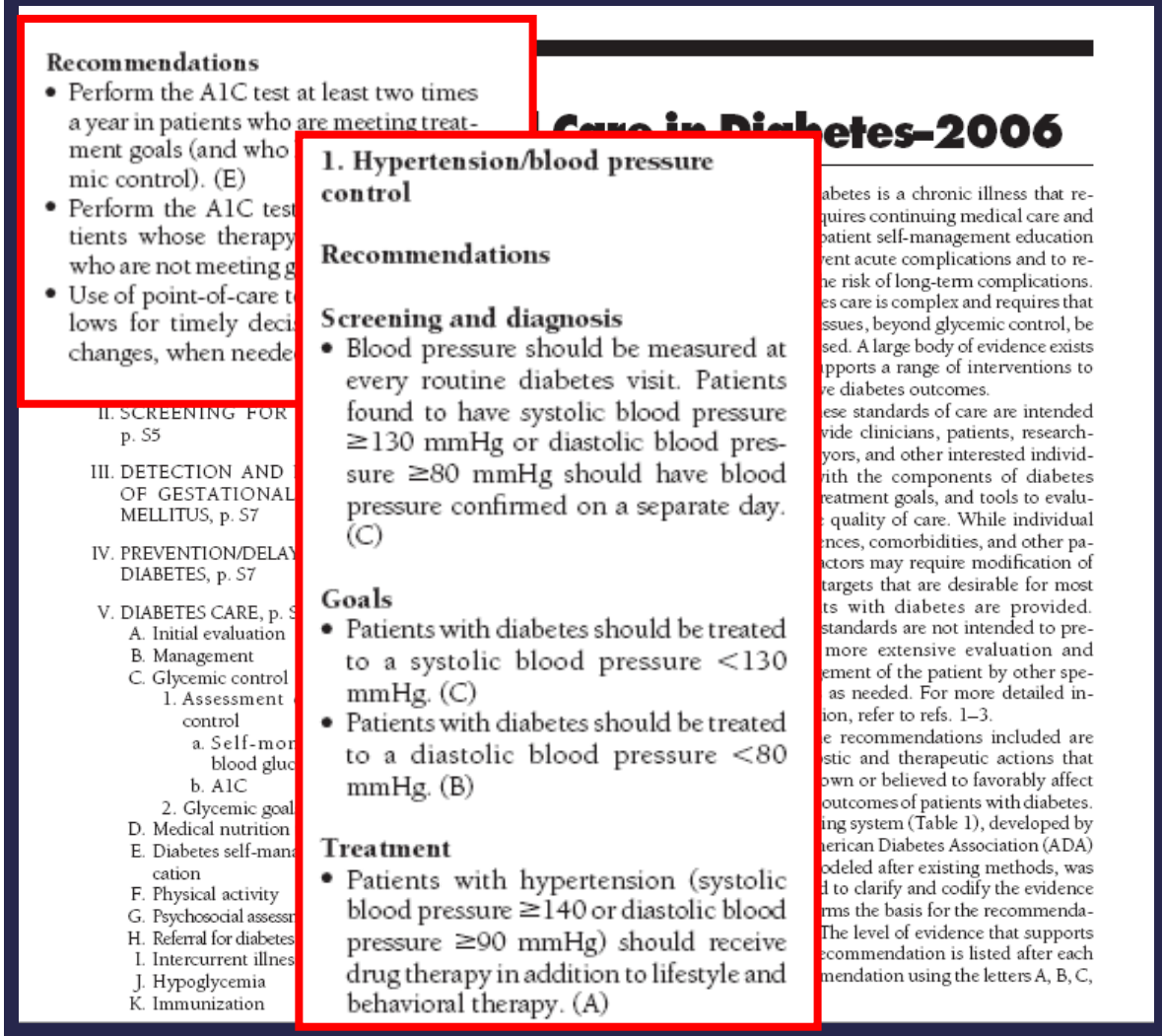

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2. Dyslipidemia/lipid management

Recommendations

Screening
- In adult patients, test for lipid disorders at least annually and more often if needed to achieve goals. In adults with low-risk lipid values (LDL <100 mg/dl, HDL >50 mg/dl, and triglycerides <150 mg/dl), lipid assessments may be repeated every 2 years. (E)

Treatment recommendations and goals
- Lifestyle modification focusing on the reduction of saturated fat and cholesterol intake, weight loss (if indicated), and increased physical activity has been shown to improve the lipid profile in patients with diabetes. (A)
- In individuals without overt CVD
  - The primary goal is an LDL <100 mg/dl (2.6 mmol/l). (A)
  - For those over the age of 40 years, statin therapy to achieve an LDL reduction of 30–40% regardless of baseline LDL levels is recommended. (A)

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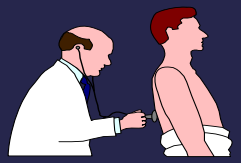
- Standards for:
  - Renal management
  - Foot care
  - Neuropathy treatment
  - Evaluation and intensity of follow-up



2. Envision Clinical Scenarios

Envision Clinical Scenarios

Goal

Provide decision support as integral part of care workflow

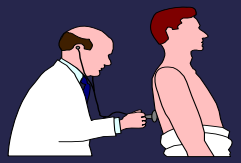
Assumption

Guideline DSS is responsive, facilitative – not controlling.
Guideline environment is workflow aware but not managing.

Formalisms

Identify opportunities in care workflow for guideline decision support.
Specify the clinical events (and context) to which SAGE must respond.
Identify guideline-based actions that SAGE should generate.
Formulate multiple strategies including background processes and population management to reinforce outcomes achievement.

SAGE



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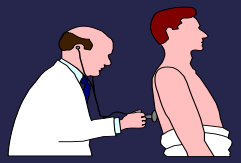
Diabetic care scenarios

- Automated enrollment for all new cases
- Visit for primary care services
- Reminders and work lists for diabetic case managers

SAGE



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Primary care scenario example:

A patient checks in to see his primary physician for routine care services. SAGE identifies diabetic guideline enrollment and refreshes alerts, reviewing criteria for treatments and testing. Blood pressure, lipids and glycohemoglobin are compared to goals individualized for this patient. The physician is notified of deficiencies, prompted to complete necessary examinations and reminded to address co-morbidities such as smoking and obesity when appropriate.

SAGE

3. Formalize Guideline Logic

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- Ambiguity and Guideline Statements
  - Uncertain concepts require definition
  - Clinical investigators resolve vague directions with clinical experts

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Immunization guideline:
"Progressive encephalopathy is contraindication to administration of DTaP"

Progressive encephalopathy is defined as the presence of
Encephalopathy AND
(Progressive neurological finding OR
Developmental delay OR
Tuberous sclerosis OR
Lennox-Gestaut syndrome)"

SAGE

3. Formalize Guideline Logic

Formalize Guideline Logic

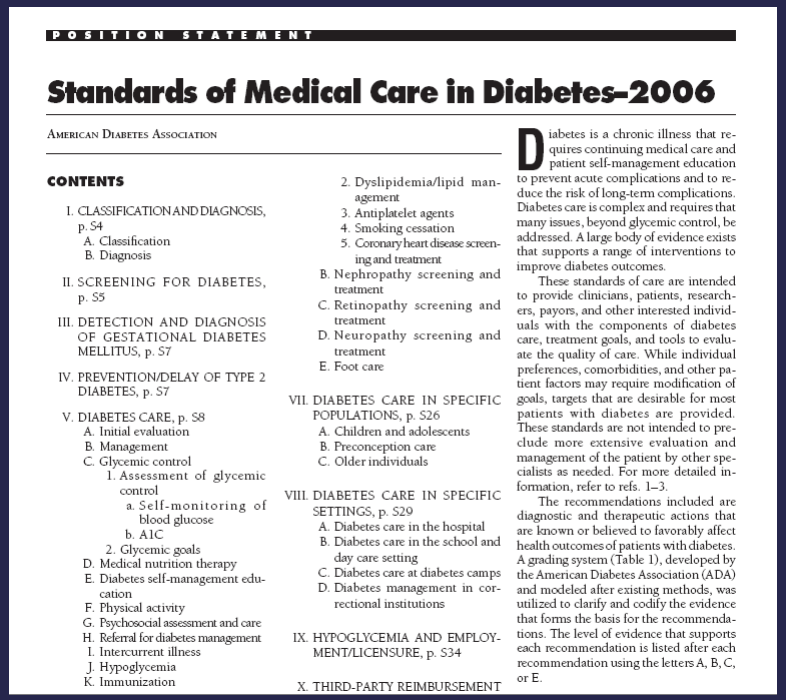
- Ambiguity and Guideline Statements
  - Uncertain concepts require definition
  - Clinical investigators resolve vague directions with clinical experts
- Focus guideline logic on requirements of clinical implementation scenario

SAGE

3. Formalize Guideline Logic

Formalize Guideline Logic

"Determine if glycemic control is on target"



POSITION STATEMENT

Standards of Medical Care in Diabetes–2006

American Diabetes Association

CONTENTS

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IF (date of last Glycohemoglobin
within 6 months AND
Glycohemoglobin within Goal)
OR
date of last Glycohemoglobin
within 3 months
OR
Glycohemoglobin ordered
THEN
Continue
ELSE
Order Glycohemoglobin

4. Define Guideline Concepts

Define Guideline Concepts

Guideline concept references must be extracted from guideline statements:

ADA: ***diabetic patients over 55 years, with hypertension or with another cardiovascular risk factor, should be considered for an angiotensin-converting enzyme inhibitor***

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Guideline concept references must be extracted from guideline statements:

ADA: ***diabetic patients over 55 years, with hypertension or with another cardiovascular risk factor, should be considered for an angiotensin-converting enzyme inhibitor***

Risk factors include:

- History of cardiovascular disease
- Family history of coronary disease
- Dyslipidemia
- Microalbuminuria
- Smoking

Concepts must be contextualized, disambiguated and defined

5. Formalize Vocabulary Inventory

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  - Post-coordination where appropriate
  - Concept expressions create logical vocabulary extensions

SAGE

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Immunization guideline:

"Maternal hepatitis B surface antigen positive
ISA Context dependent finding
ASSOCIATED FINDING Hep B antigen positive
FINDING CONTEXT Present
SUBJECT RELATIONSHIP CONTEXT Mother"

SAGE

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'Renal insufficiency syndrome: SNCT 42399005'
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6. Clarify Data Representation

Clarify Data Representation

How are patient data represented in the (real-world) clinical information system (CIS)?

"Develop or adjust the management plan to achieve normal or near-normal glycemia with an A1C test goal of ≤7% "

- Virtual medical record (VMR)
  - Simplified view of patient data assumed by the SAGE system
  - Based on HL7 Reference Information Model
- VMR class: 'Observation'

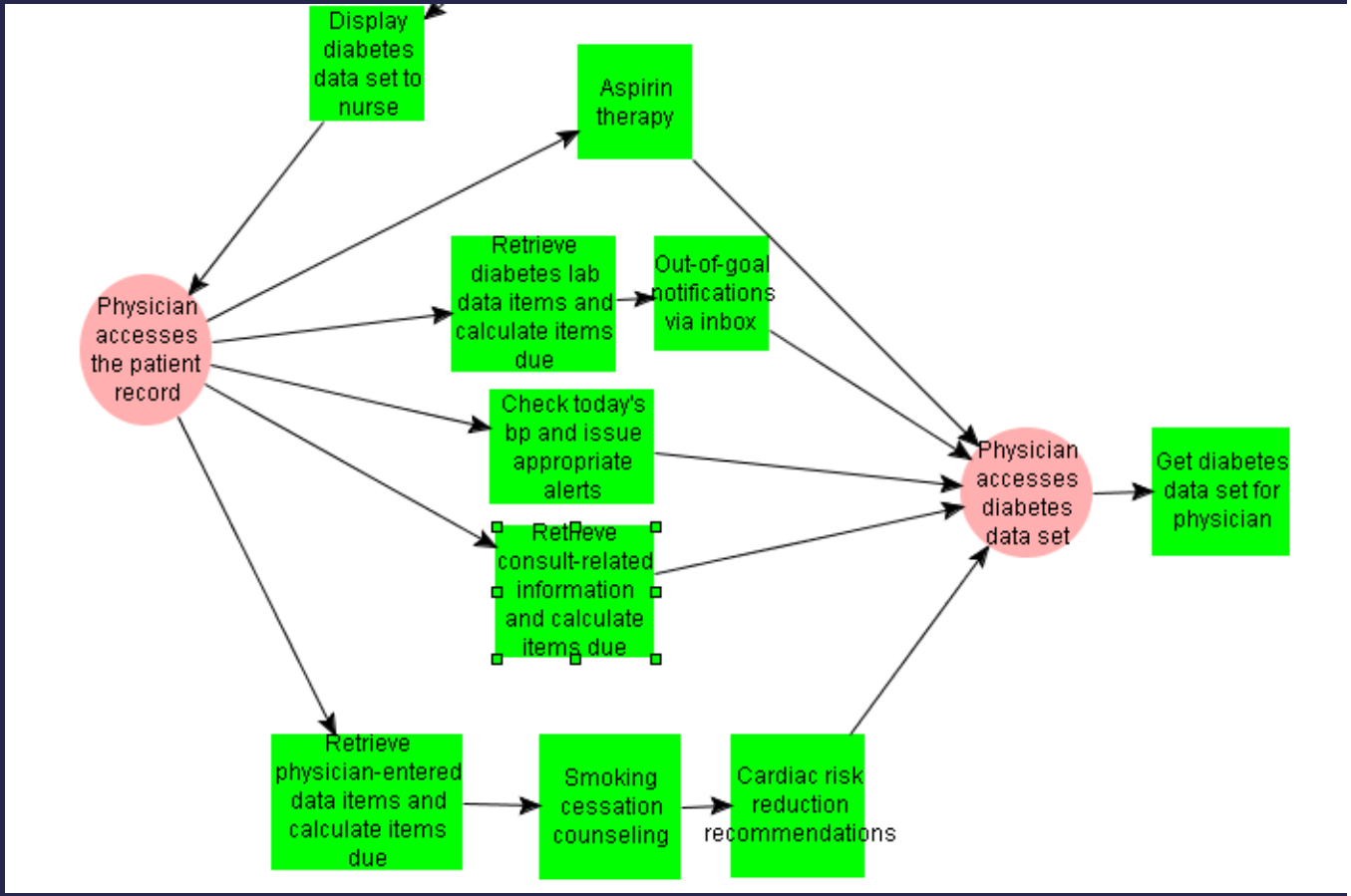
Observation.code equals
"HEMOGLOBIN A1C:TOTAL:MFR:PT:BLD:QN: LOINC 4548-4"
Observation.value < 7.0'

SAGE

7. Encode Guideline Knowledgebase

Encode Guideline Knowledge base

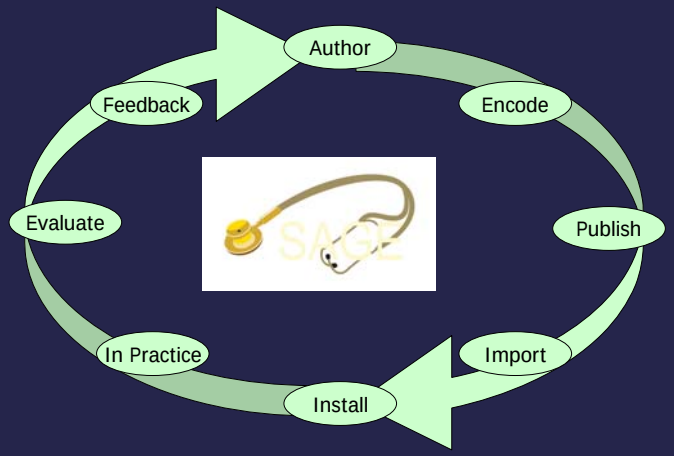
Top-level process description in encoded guideline reflects expected reactions to events in clinical workflow



Standards-based Terminology Services

- Terminology services during guideline encoding and execution

Tony Weida, Ph.D.
Apelon, Inc.



Terminology-powered Guidelines

- Standard access to standard terminologies
- Make guidelines easier to
  - Author
  - Explain
  - Share
  - Customize
  - Localize
  - Execute
- Terminology extension mechanisms
- Terminology services
  - Apelon Distributed Terminology System (DTS)
  - Authoring support via GUI tools
  - Runtime execution support via APIs

Authoring with Terminologies

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- Requirements
  - Browse, search and inspect concepts
  - Select concepts
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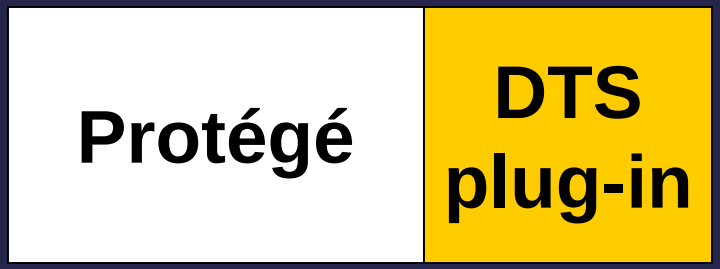

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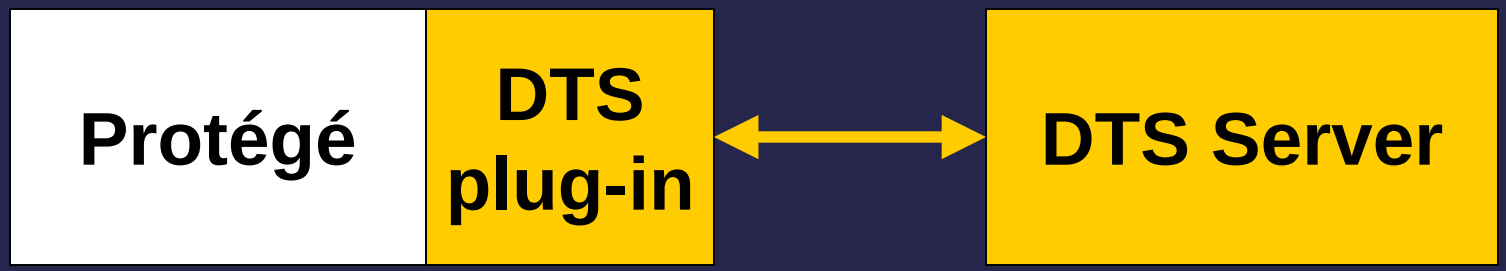

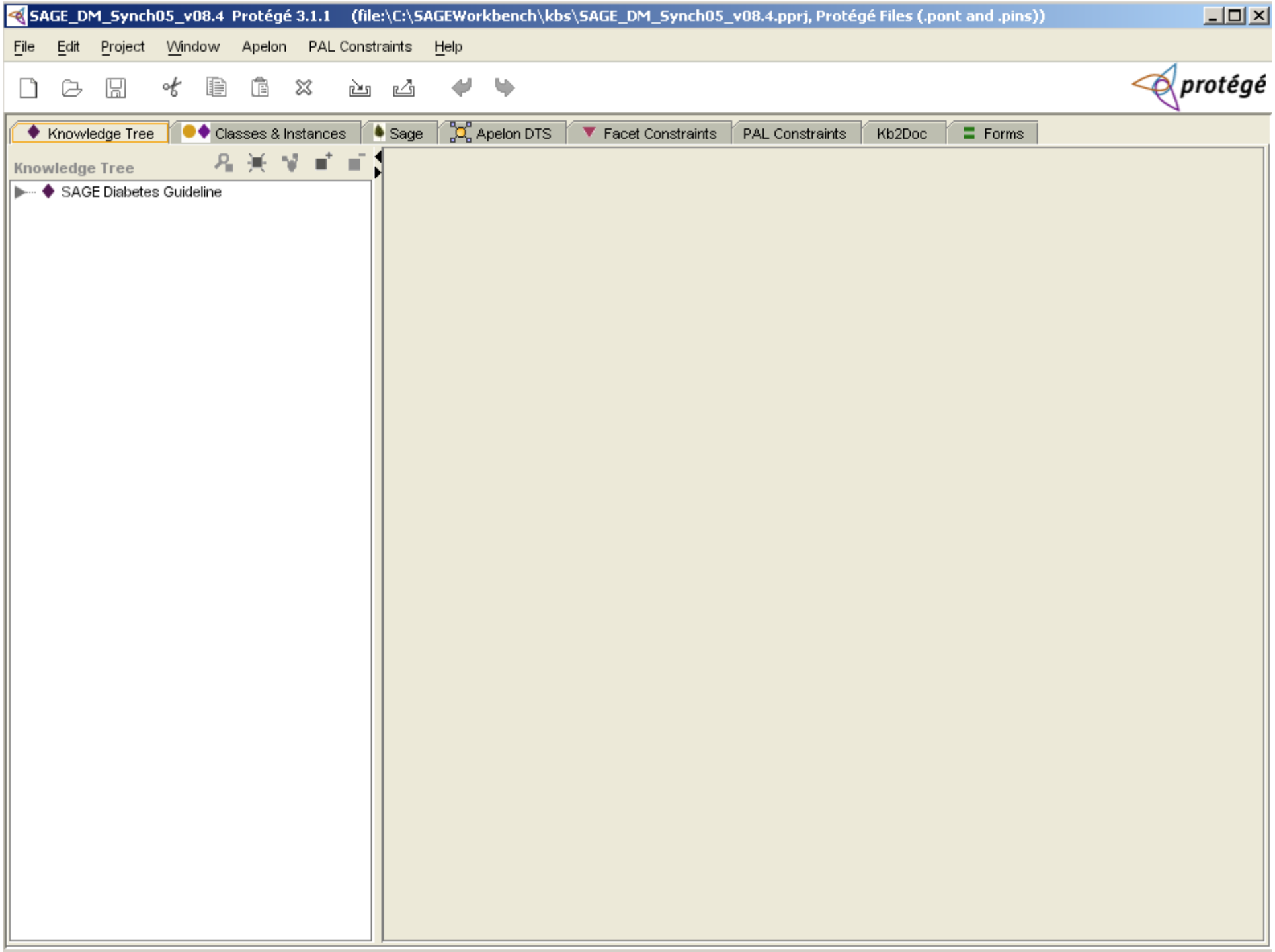
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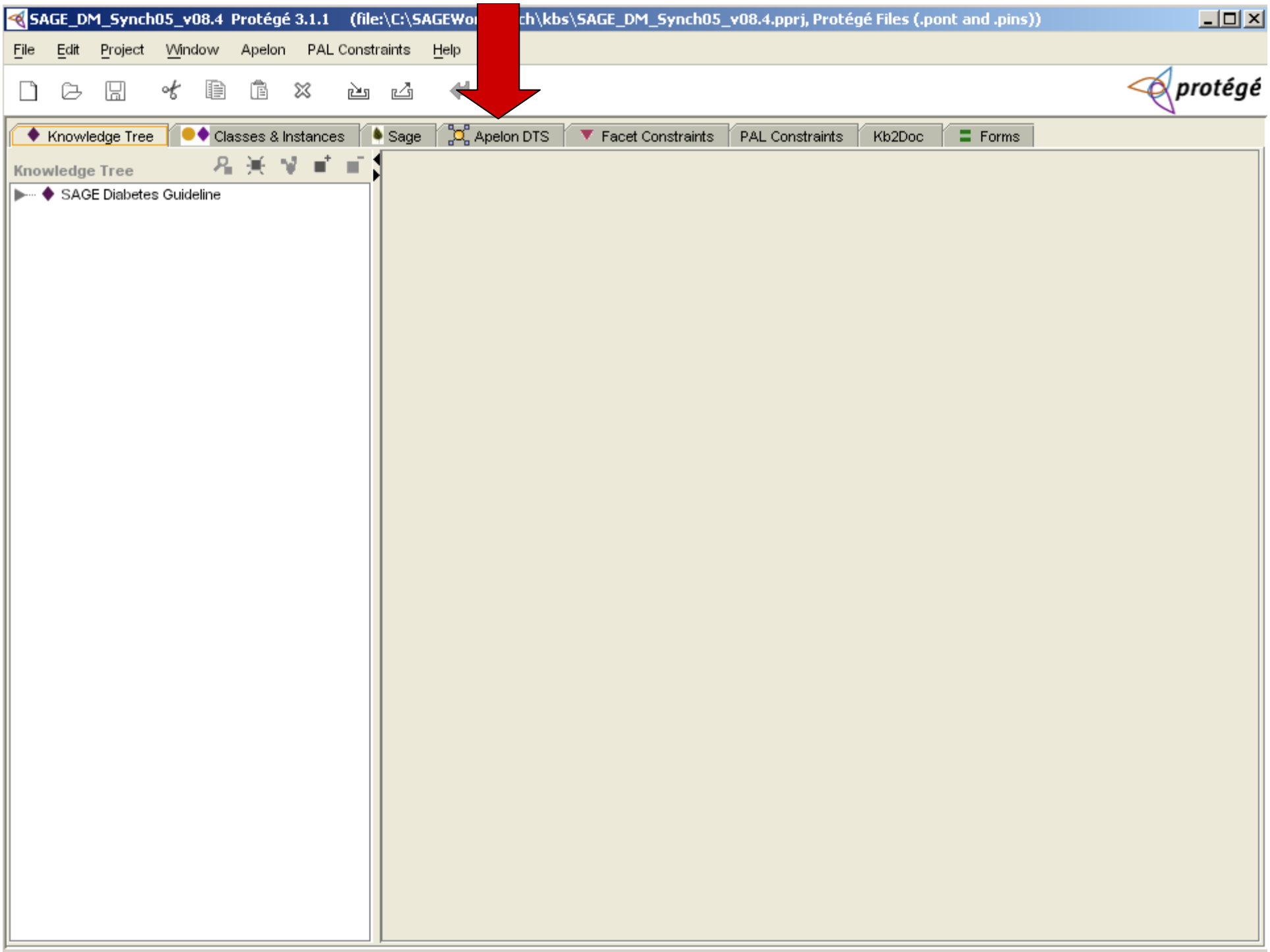
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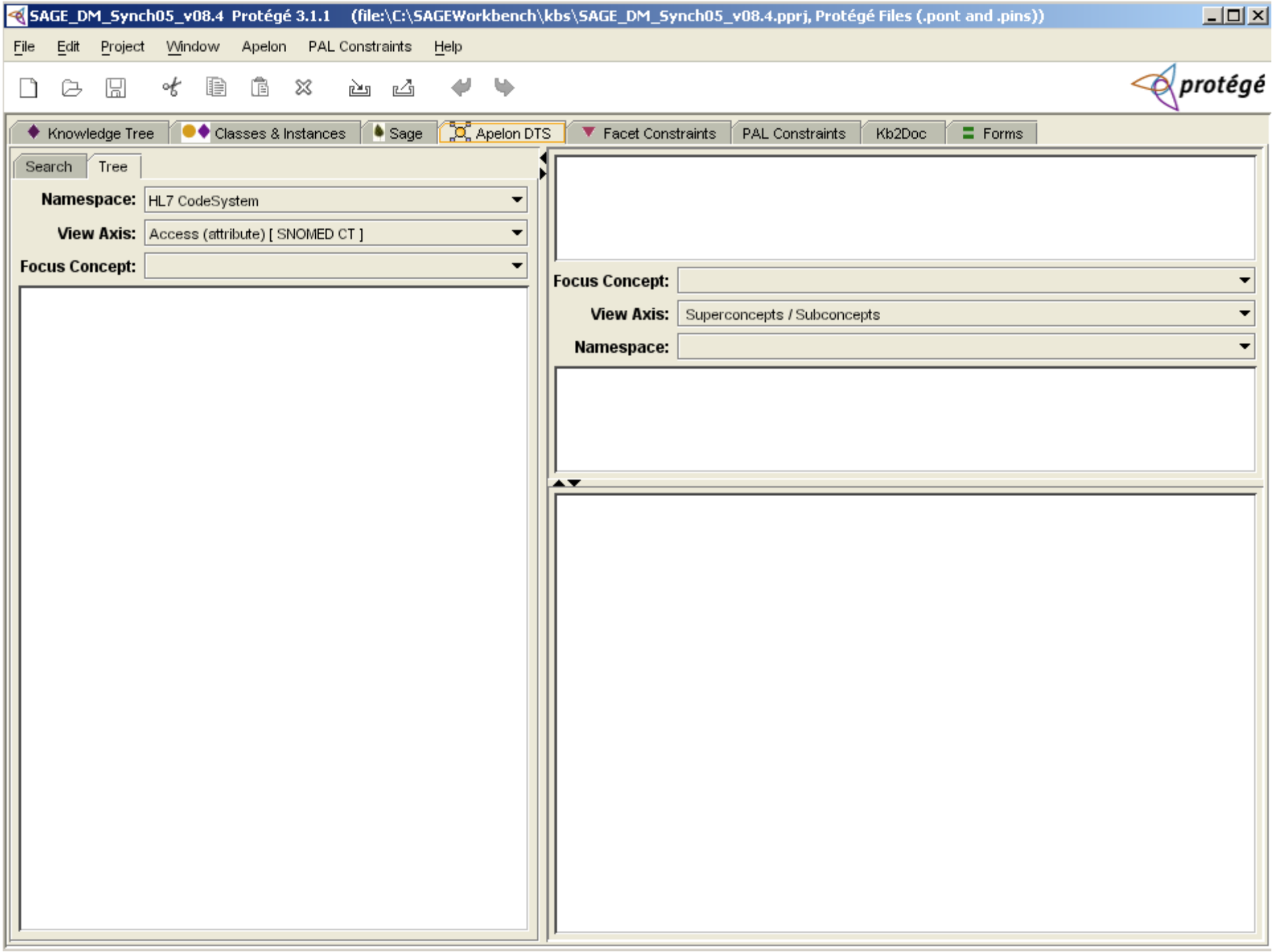
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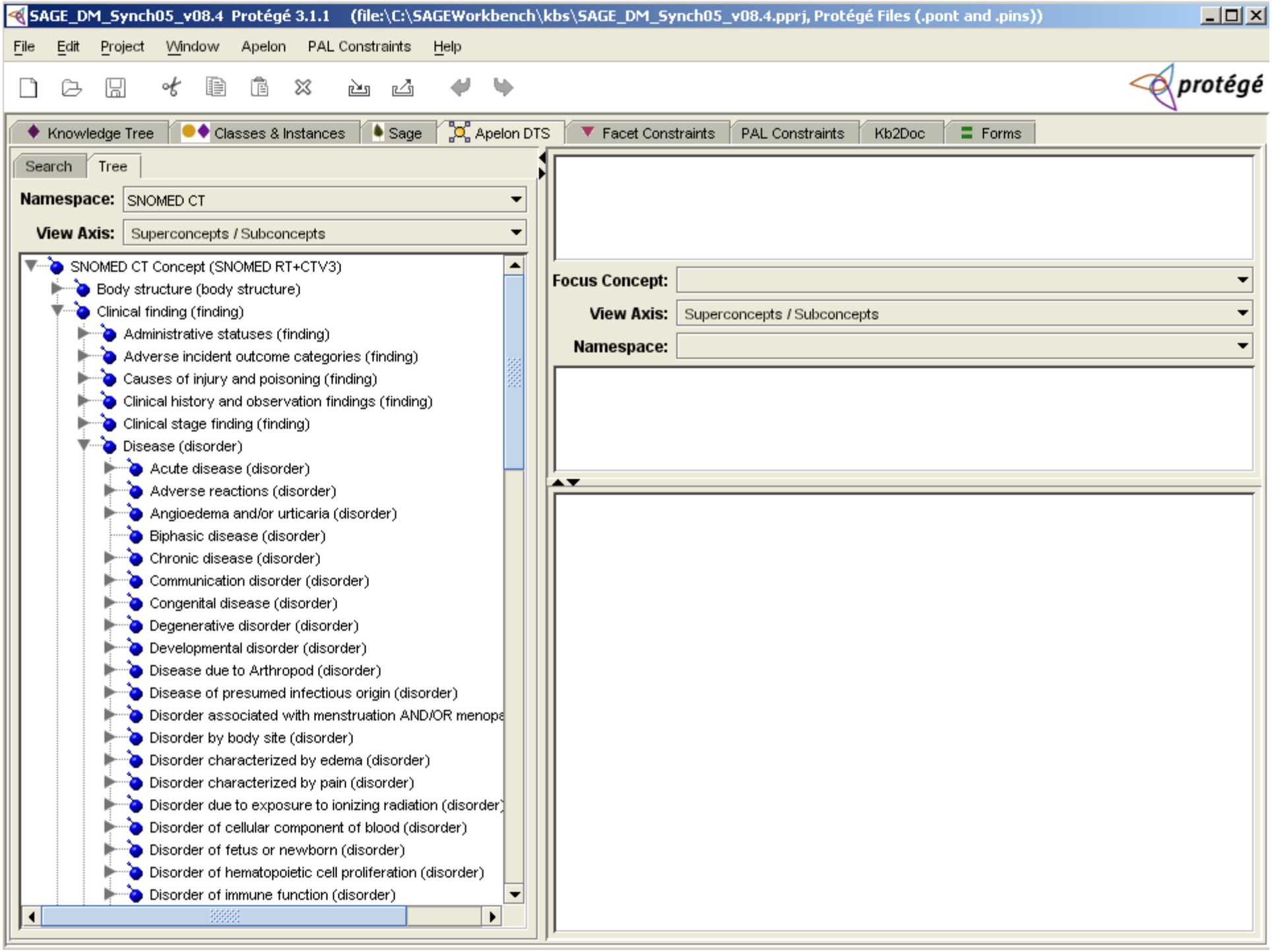
Superconcepts / Subconcepts
Namespace: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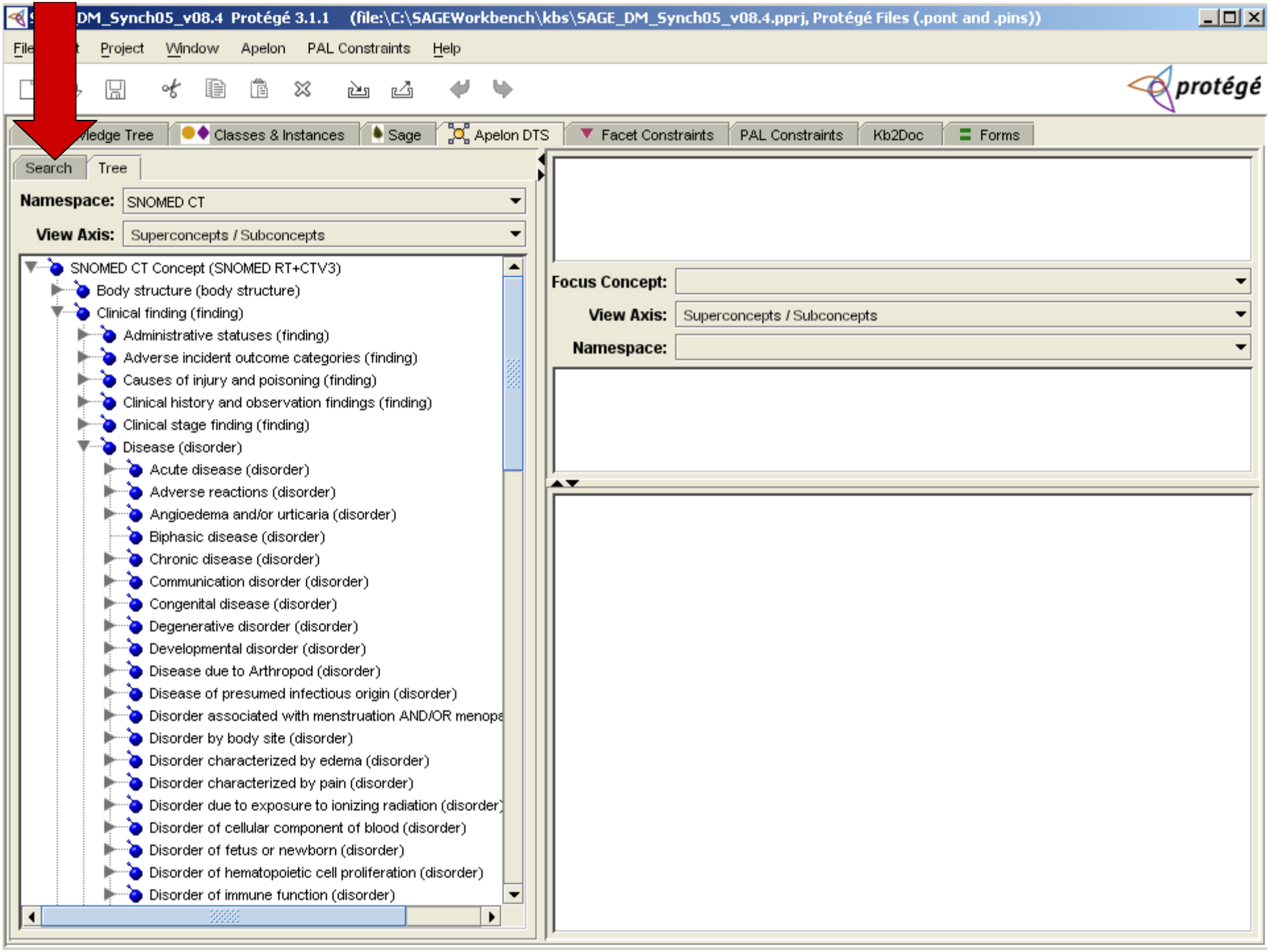
File Edit Project Window Apelon PAL Constraints Help
protégé
Knowledge Tree
Classes & Instances
Sage
Apelon DTS
Facet Constraints
PAL Constraints
Kb2Doc
Forms
Search
Tree
Namespace: SNOMED CT
View Axis: Superconcepts / Subconcepts
SNOMED CT Concept (SNOMED RT+CTV3)
Body structure (body structure)
Clinical finding (finding)
Administrative statuses (finding)
Adverse incident outcome categories (finding)
Causes of injury and poisoning (finding)
Clinical history and observation findings (finding)
Clinical stage finding (finding)
Disease (disorder)
Acute disease (disorder)
Adverse reactions (disorder)
Angioedema and/or urticaria (disorder)
Biphasic disease (disorder)
Chronic disease (disorder)
Communication disorder (disorder)
Congenital disease (disorder)
Degenerative disorder (disorder)
Developmental disorder (disorder)
Disease due to Arthropod (disorder)
Disease of presumed infectious origin (disorder)
Disorder associated with menstruation AND/OR menopa
Disorder by body site (disorder)
Disorder characterized by edema (disorder)
Disorder characterized by pain (disorder)
Disorder due to exposure to ionizing radiation (disorder)
Disorder of cellular component of blood (disorder)
Disorder of fetus or newborn (disorder)
Disorder of hematopoietic cell proliferation (disorder)
Disorder of immune function (disorder)
Focus Concept:
View Axis: Superconcepts / Subconcepts
Namespace: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PAL Constraints
Kb2Doc
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Search
Tree
Namespace:
SNOMED CT
View Axis:
Superconcepts / Subconcepts
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Body structure (body structure)
Clinical finding (finding)
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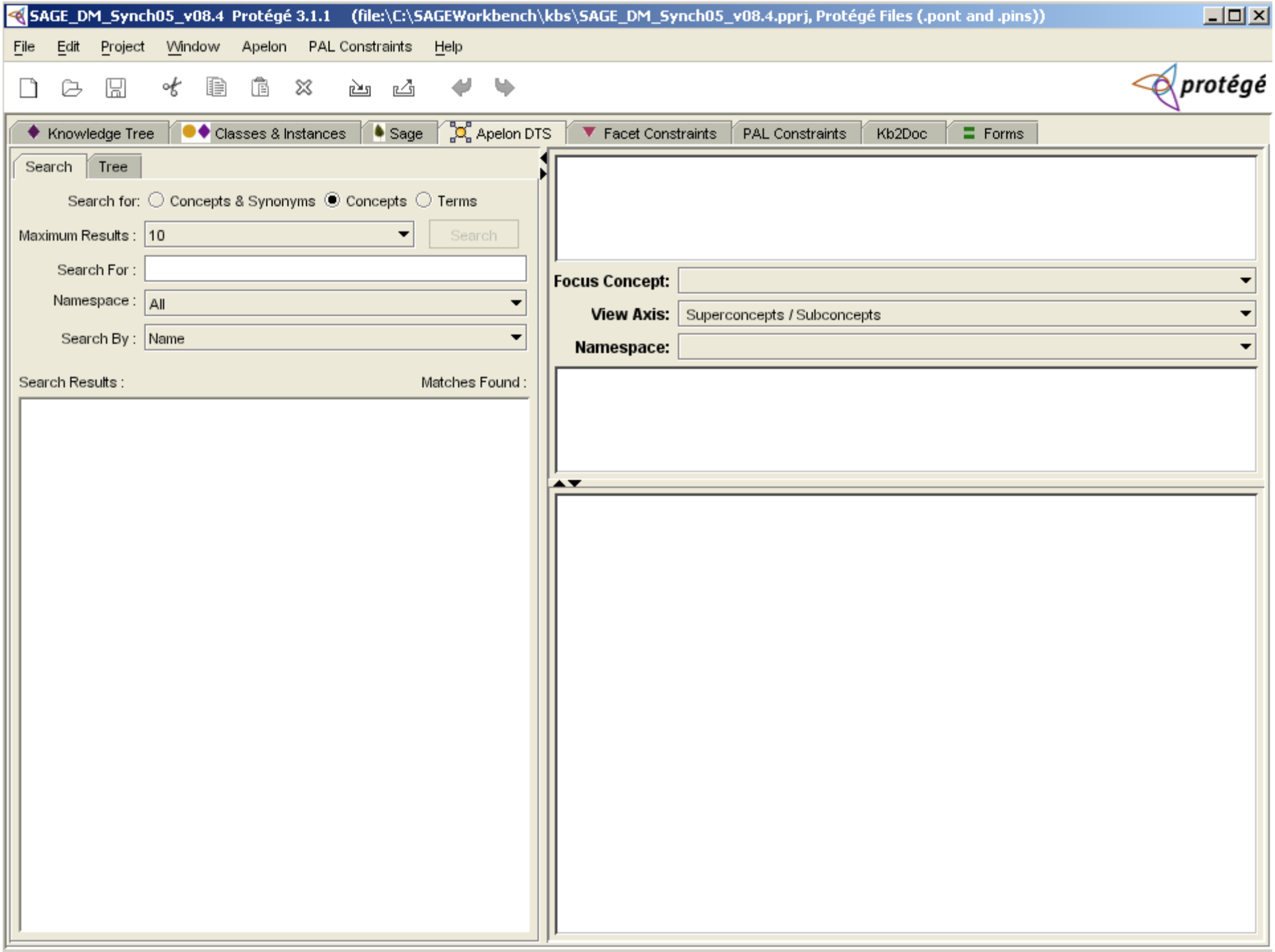
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Tree
Search for: Concepts & Synonyms Concepts Terms
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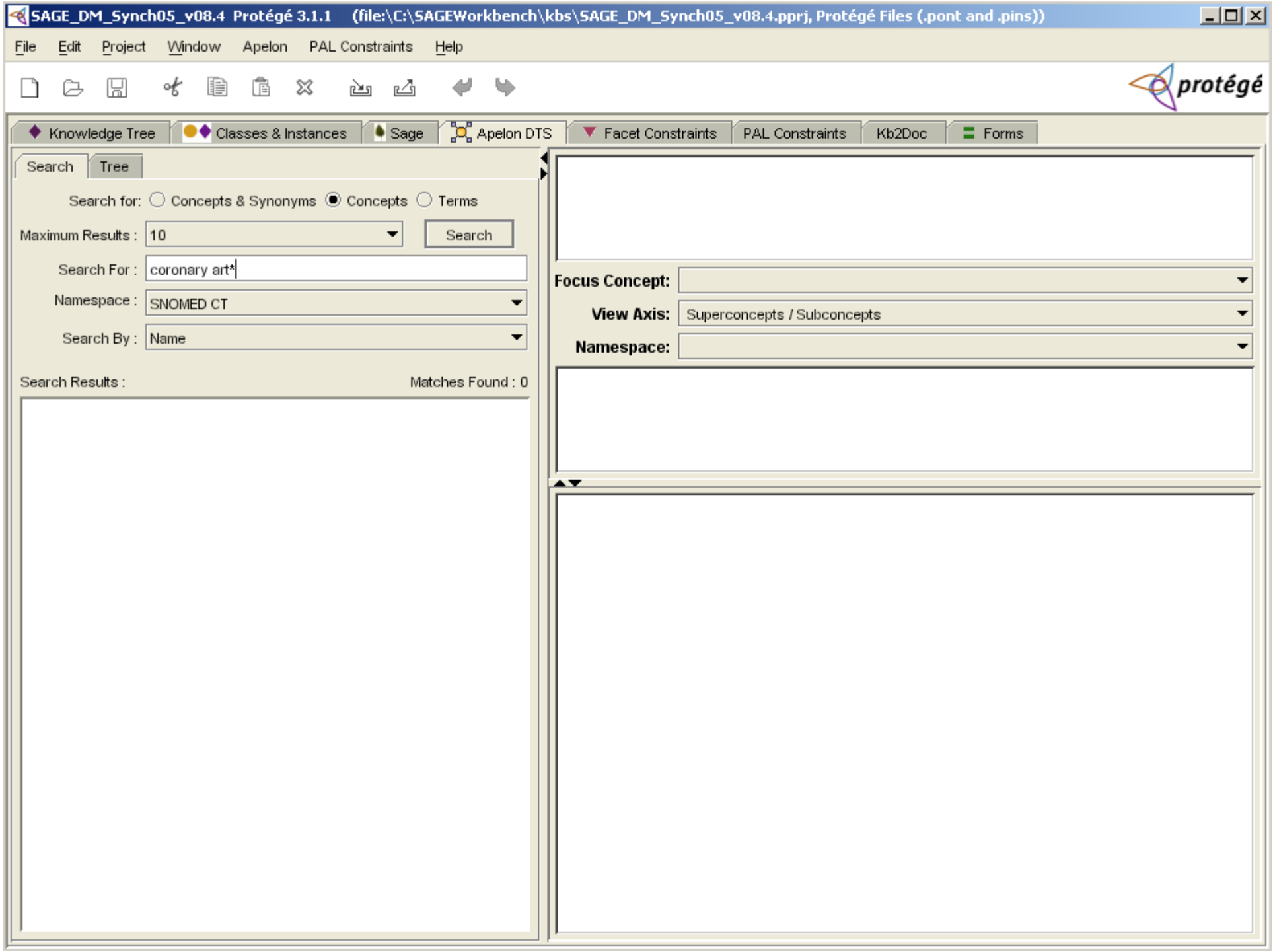
Namespace: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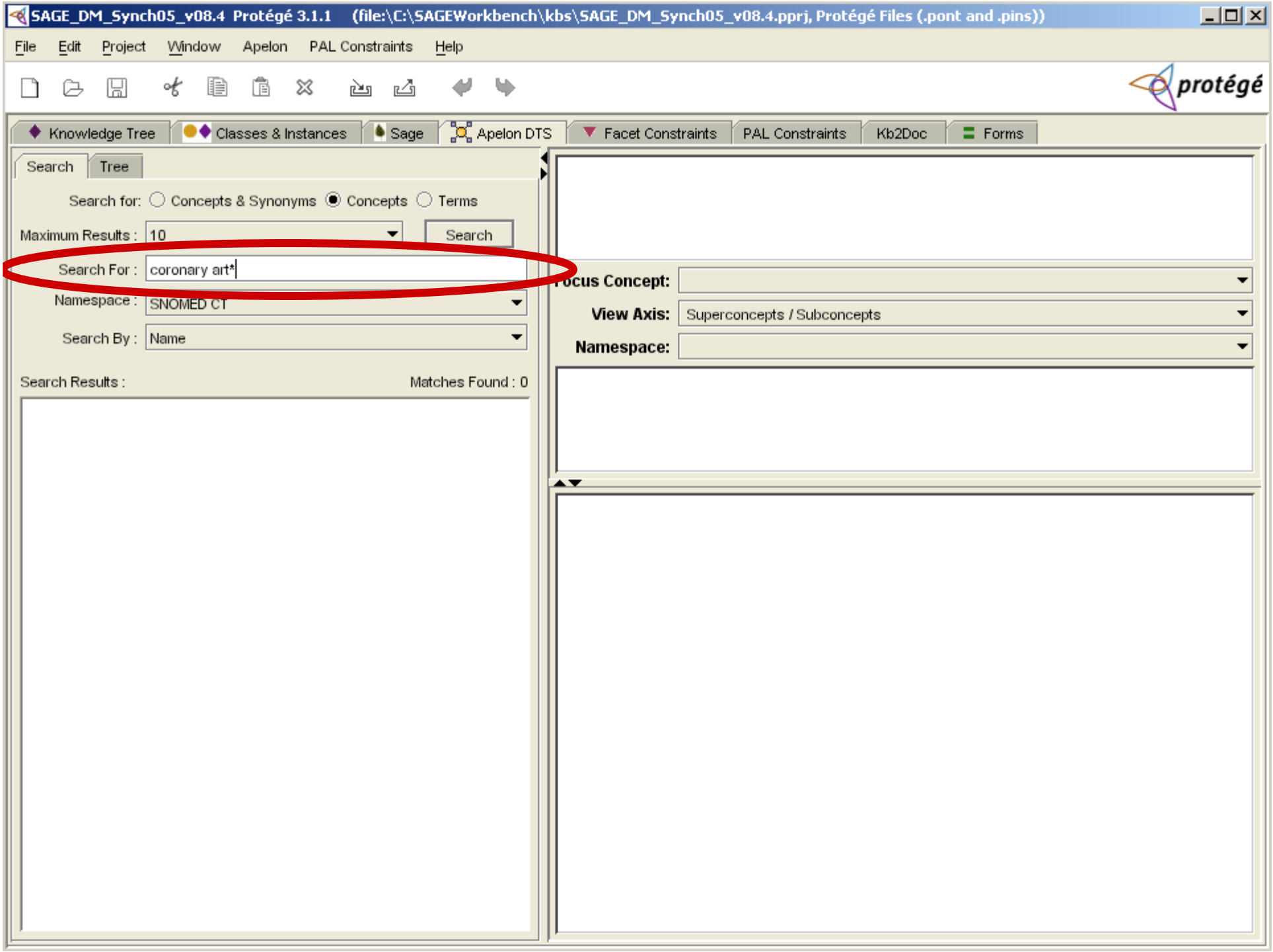
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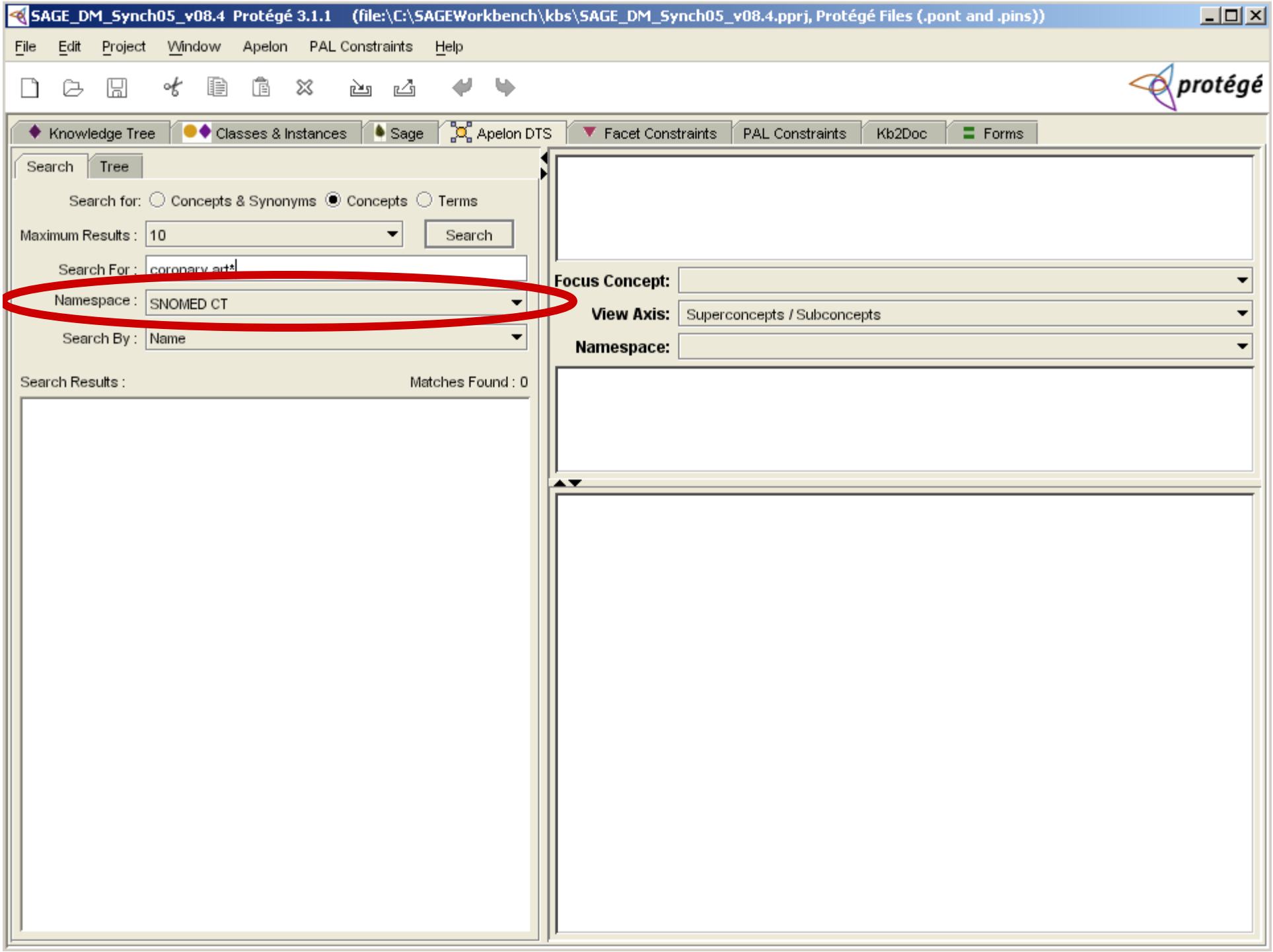
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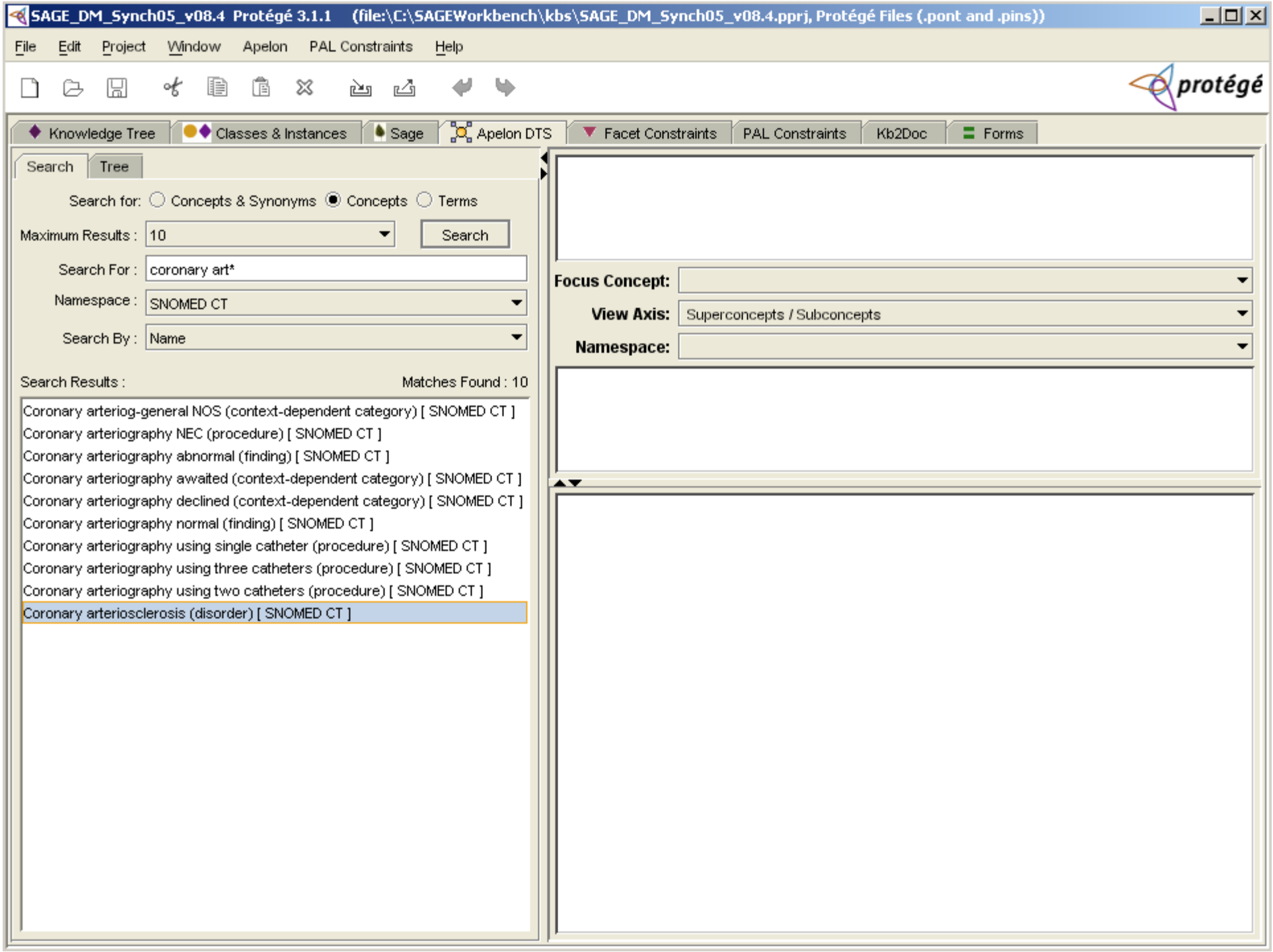
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Coronary arteriography abnormal (finding) [SNOMED CT]
Coronary arteriography awaited (context-dependent category) [SNOMED CT]
Coronary arteriography declined (context-dependent category) [SNOMED CT]
Coronary arteriography normal (finding) [SNOMED CT]
Coronary arteriography using single catheter (procedure) [SNOMED CT]
Coronary arteriography using three catheters (procedure) [SNOMED CT]
Coronary arteriography using two catheters (procedure) [SNOMED CT]
Coronary arteriosclerosis (disorder) [SNOMED CT]
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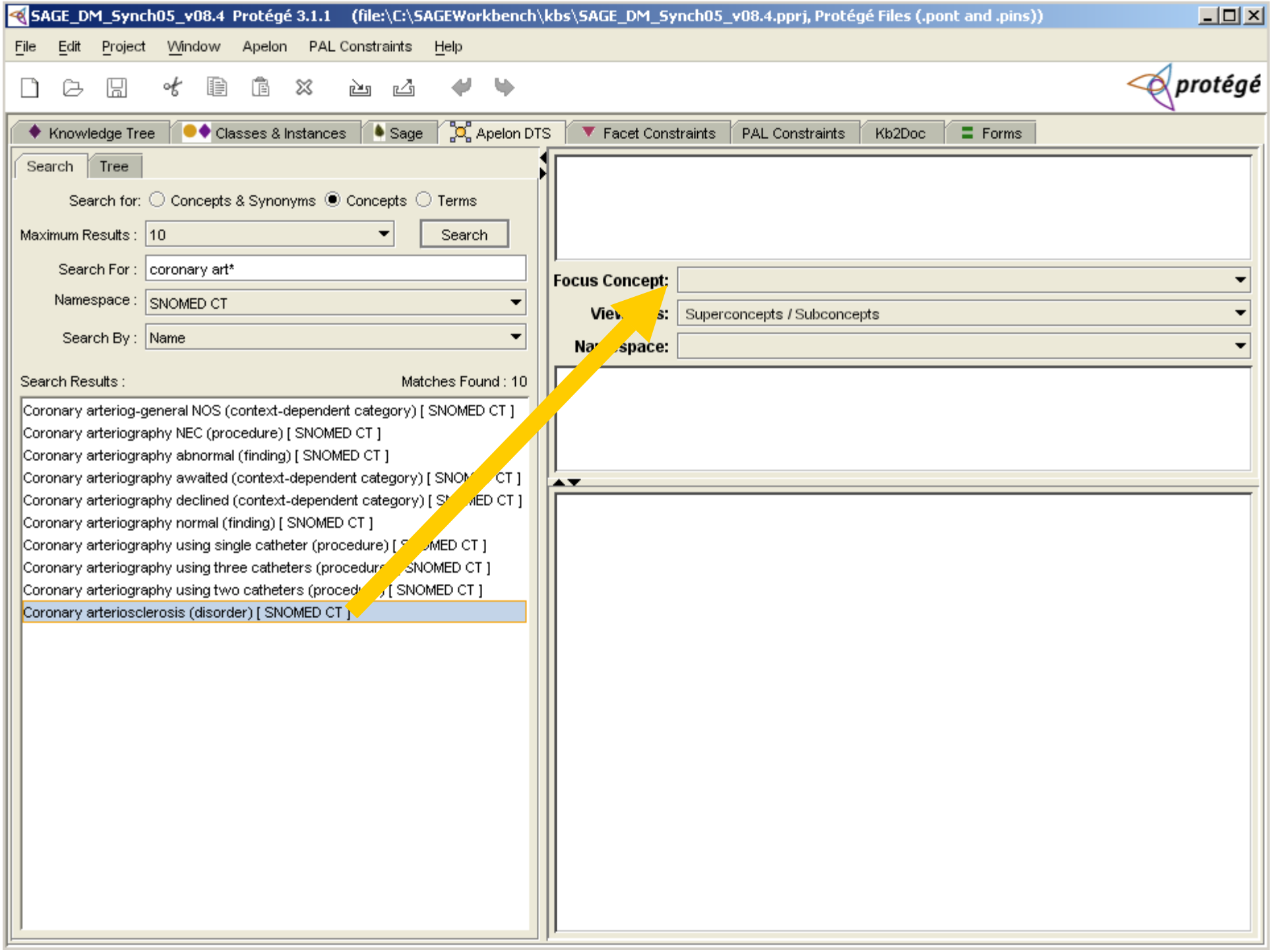
Namespace: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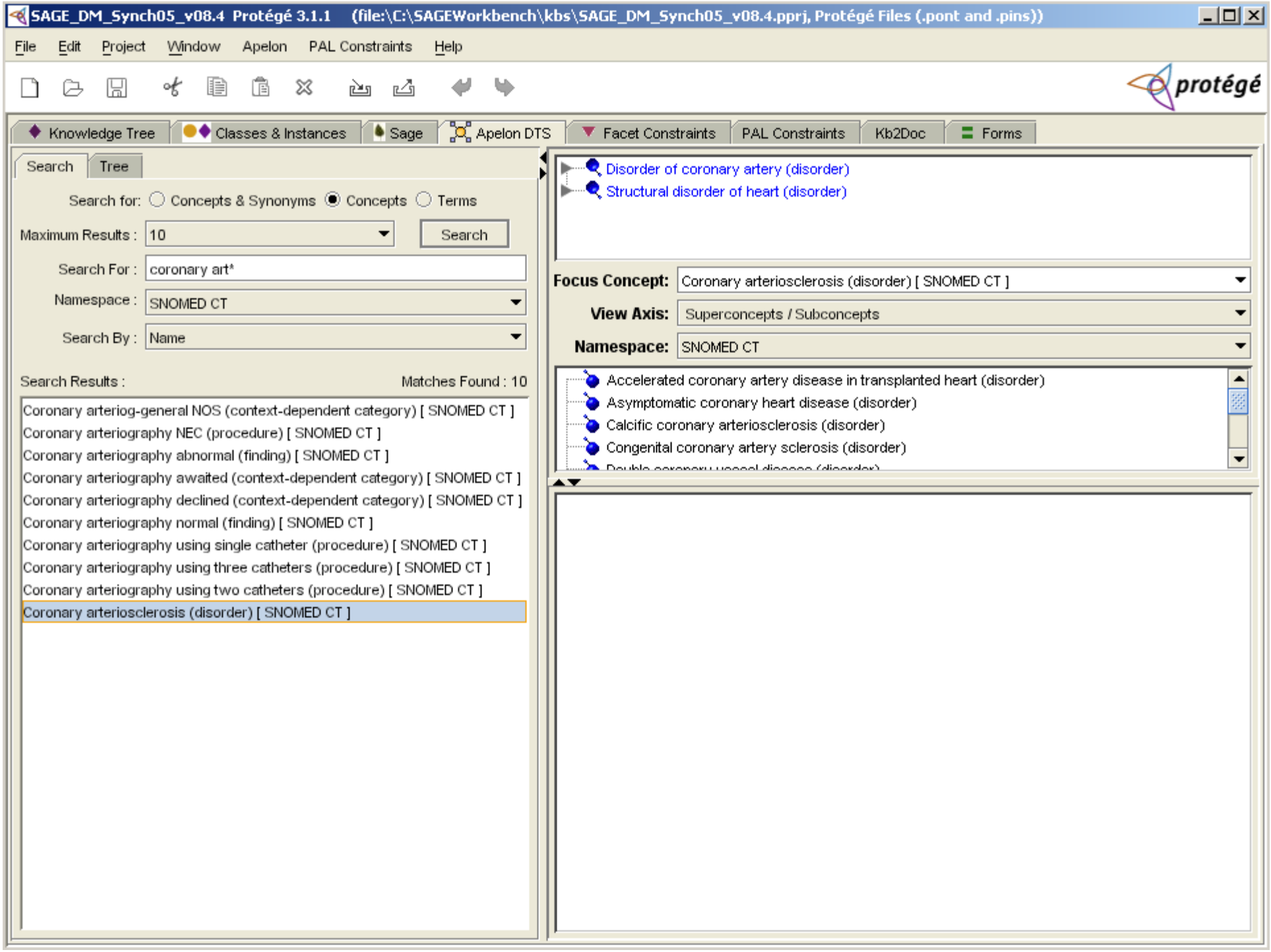
Focus Concept:
Superconcepts / Subconcepts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Coronary arteriosclerosis (disorder) [SNOMED CT]
Disorder of coronary artery (disorder)
Structural disorder of heart (disorder)
Focus Concept: Coronary arteriosclerosis (disorder) [SNOMED CT]
View Axis: Superconcepts / Subconcepts
Namespace: SNOMED CT
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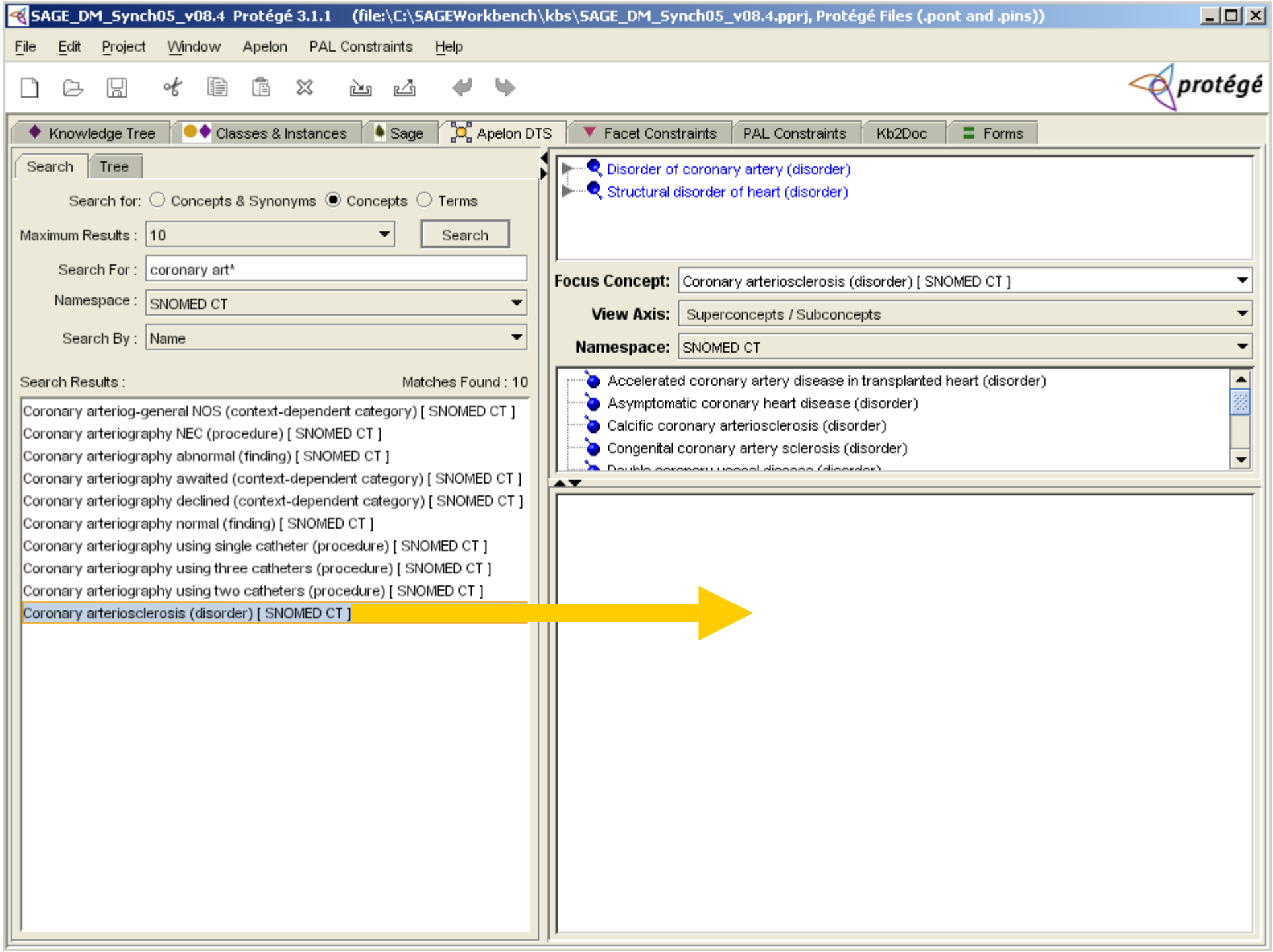
Asymptomatic coronary heart disease (disorder)
Calcific coronary arteriosclerosis (disorder)
Congenital coronary artery sclerosis (disorder)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Calcific coronary arteriosclerosis (disorder)
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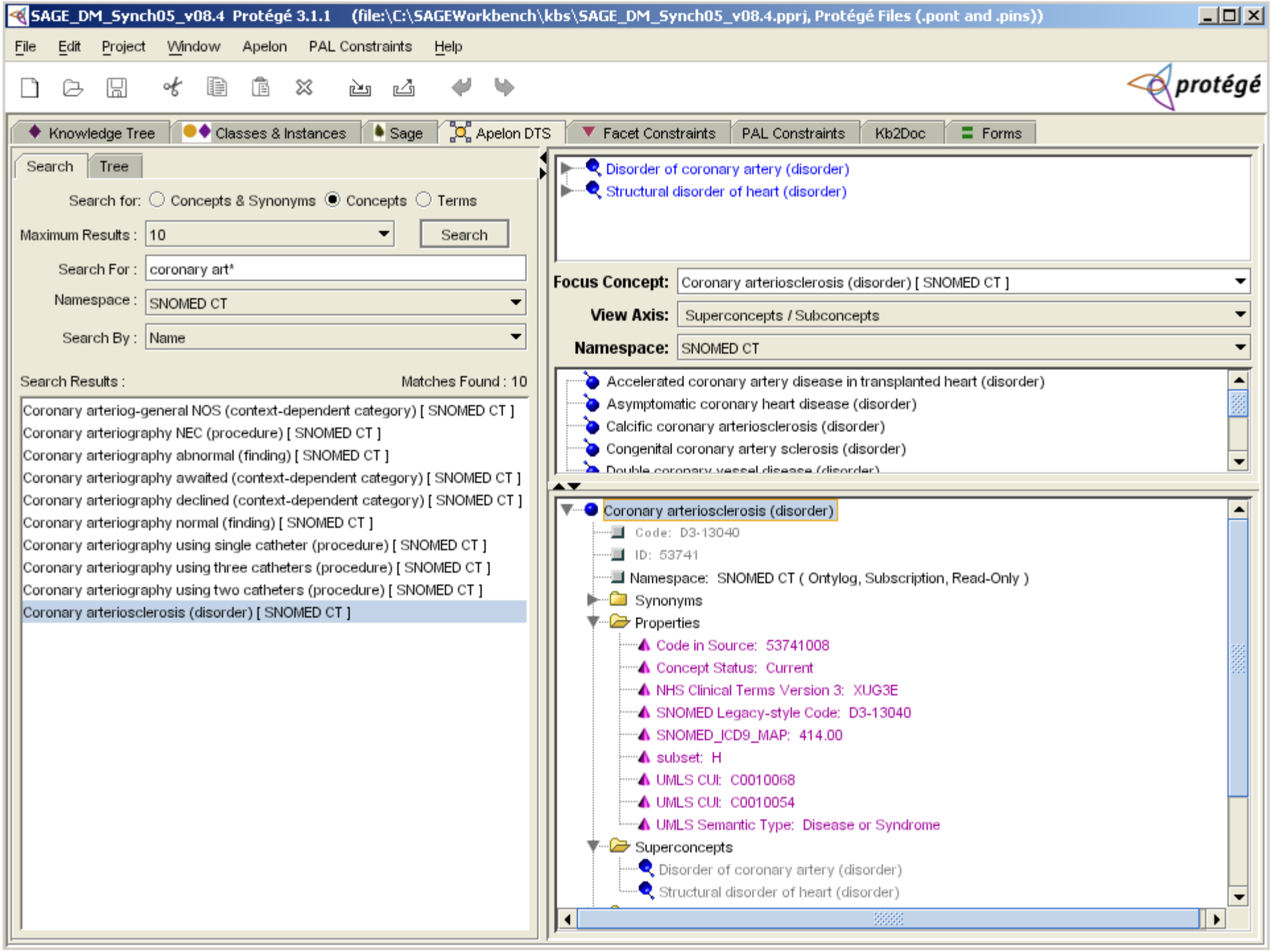
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Congenital coronary artery sclerosis (disorder)
Coronary arteriosclerosis (disorder)
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ID: 53741
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Synonyms
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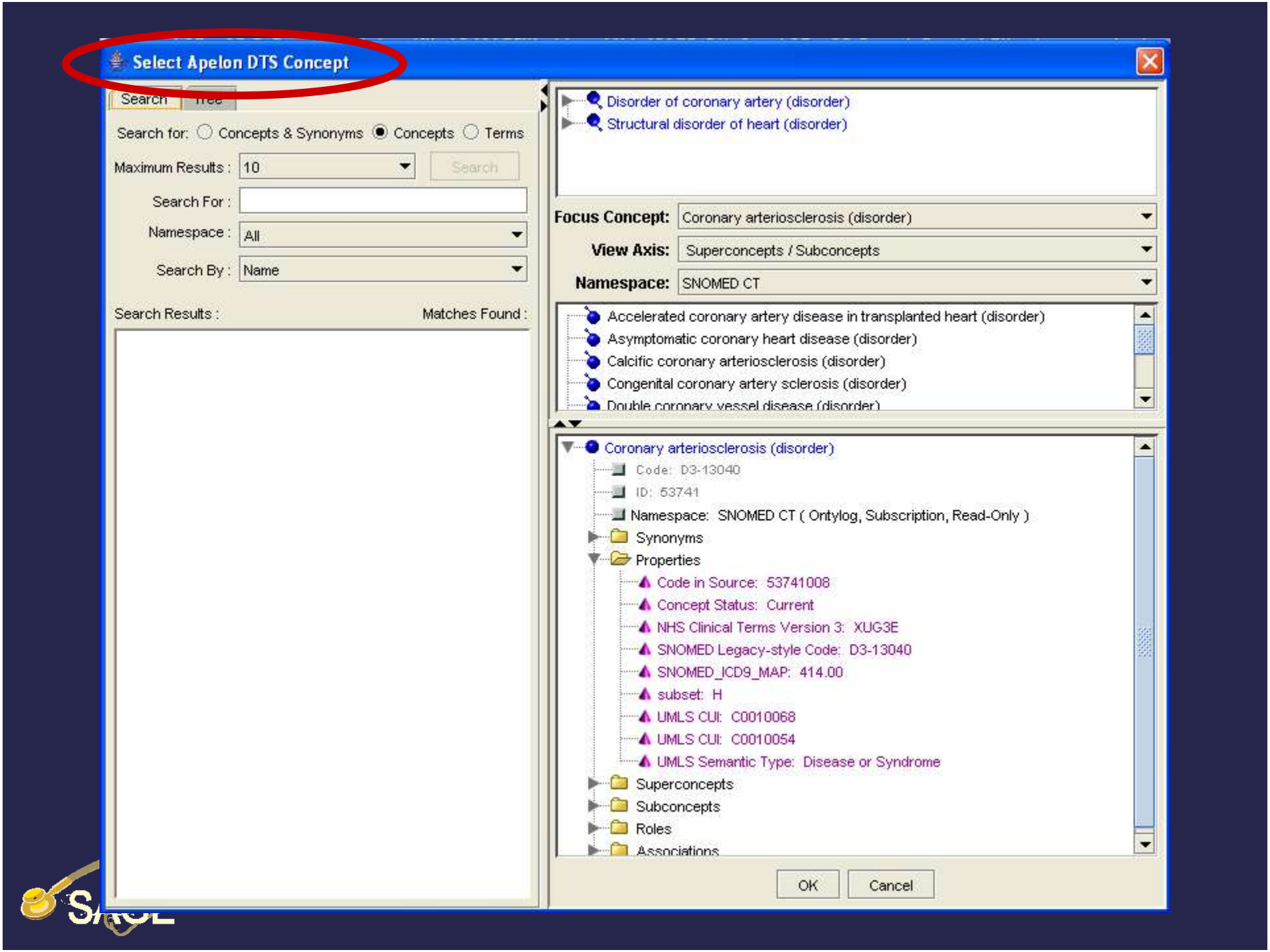
Structural disorder of heart (disorder)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Structural disorder of heart (disorder)
Focus Concept: Coronary arteriosclerosis (disorder)
View Axis: Superconcepts / Subconcepts
Namespace: SNOMED CT
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Asymptomatic coronary heart disease (disorder)
Calcific coronary arteriosclerosis (disorder)
Congenital coronary artery sclerosis (disorder)
Double coronary vessel disease (disorder)
Coronary arteriosclerosis (disorder)
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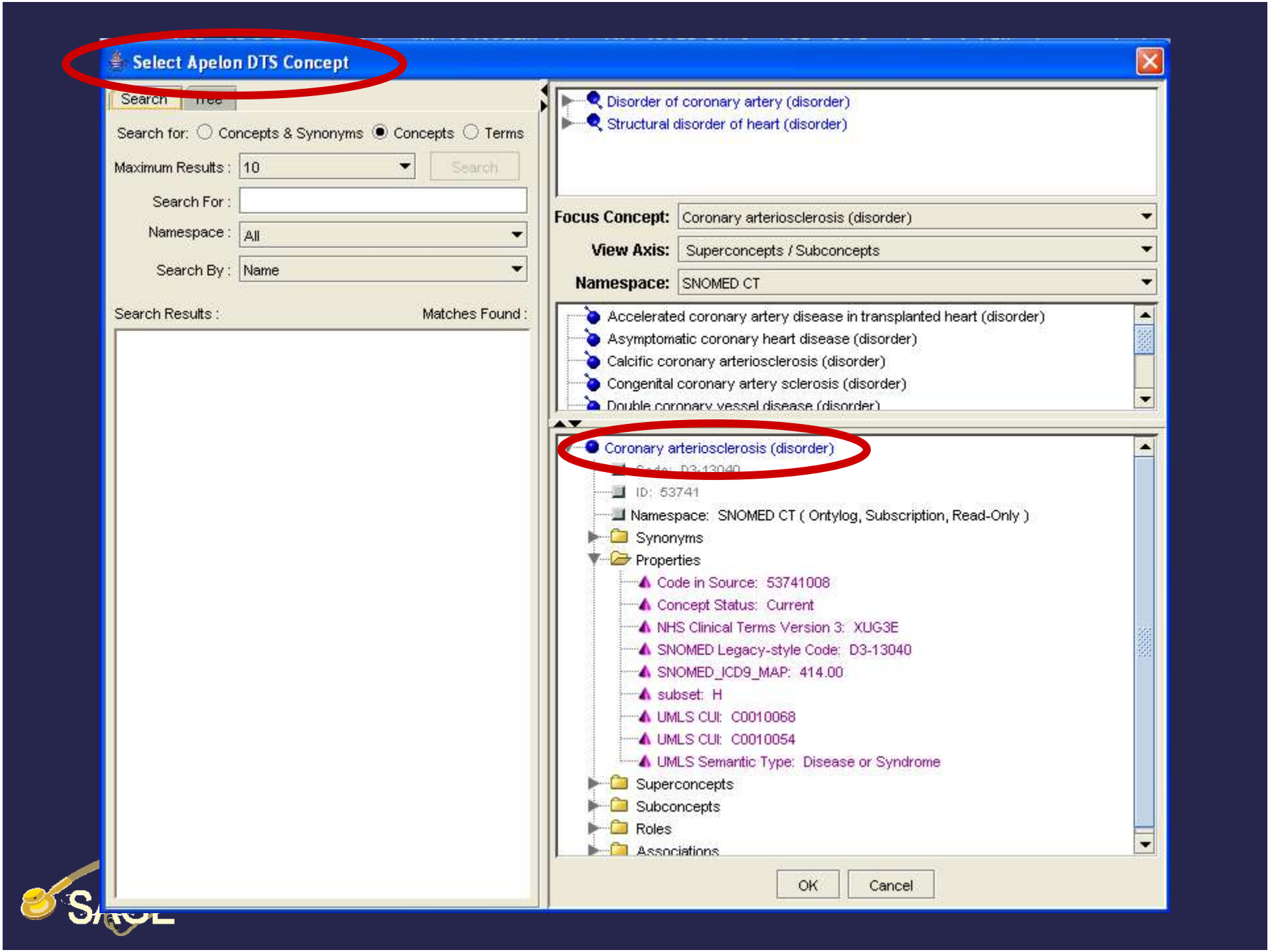
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Structural disorder of heart (disorder)
Focus Concept: Coronary arteriosclerosis (disorder)
View Axis: Superconcepts / Subconcepts
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ID: 53741
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Synonyms
Properties
Code in Source: 53741008
Concept Status: Current
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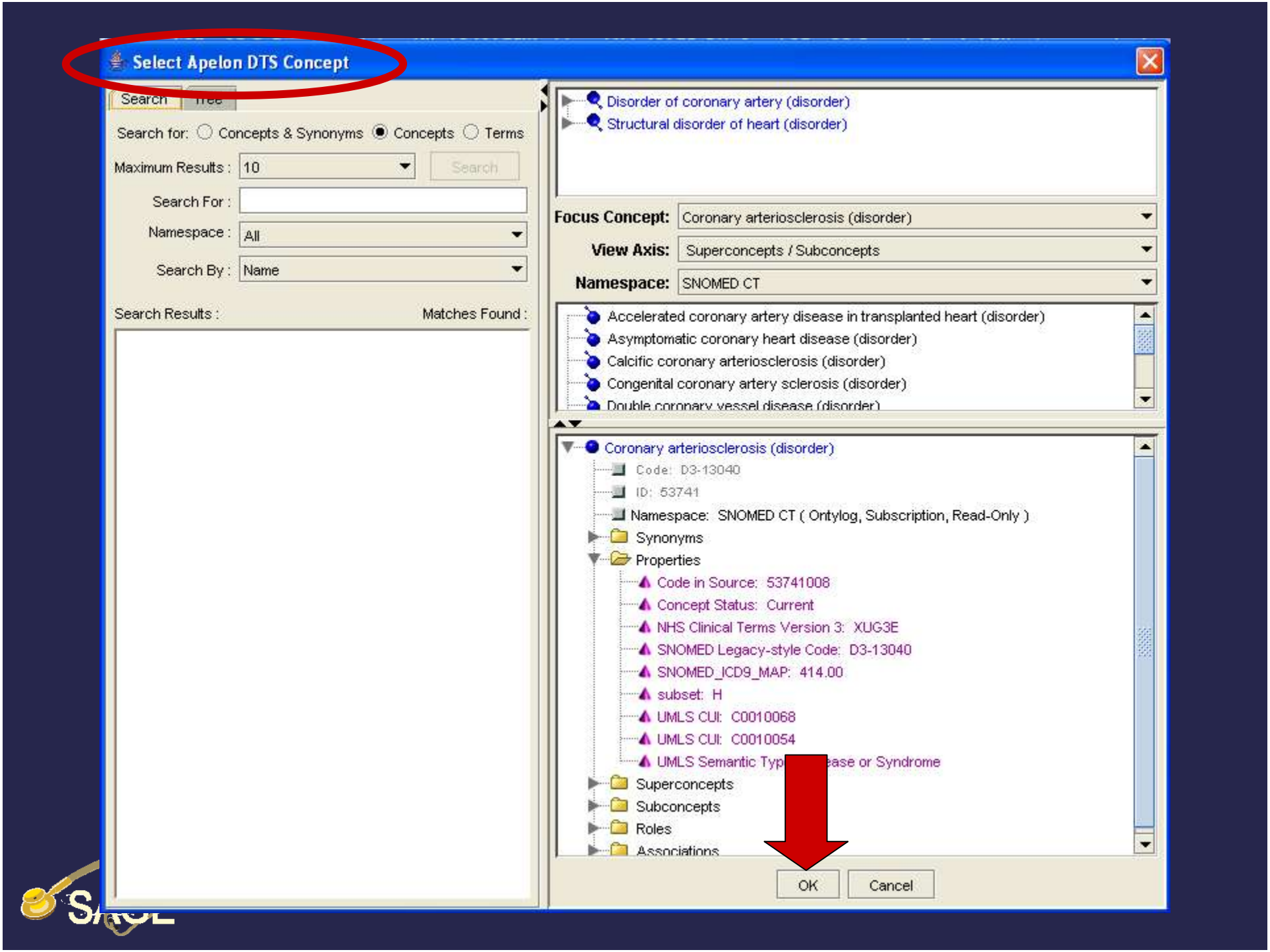
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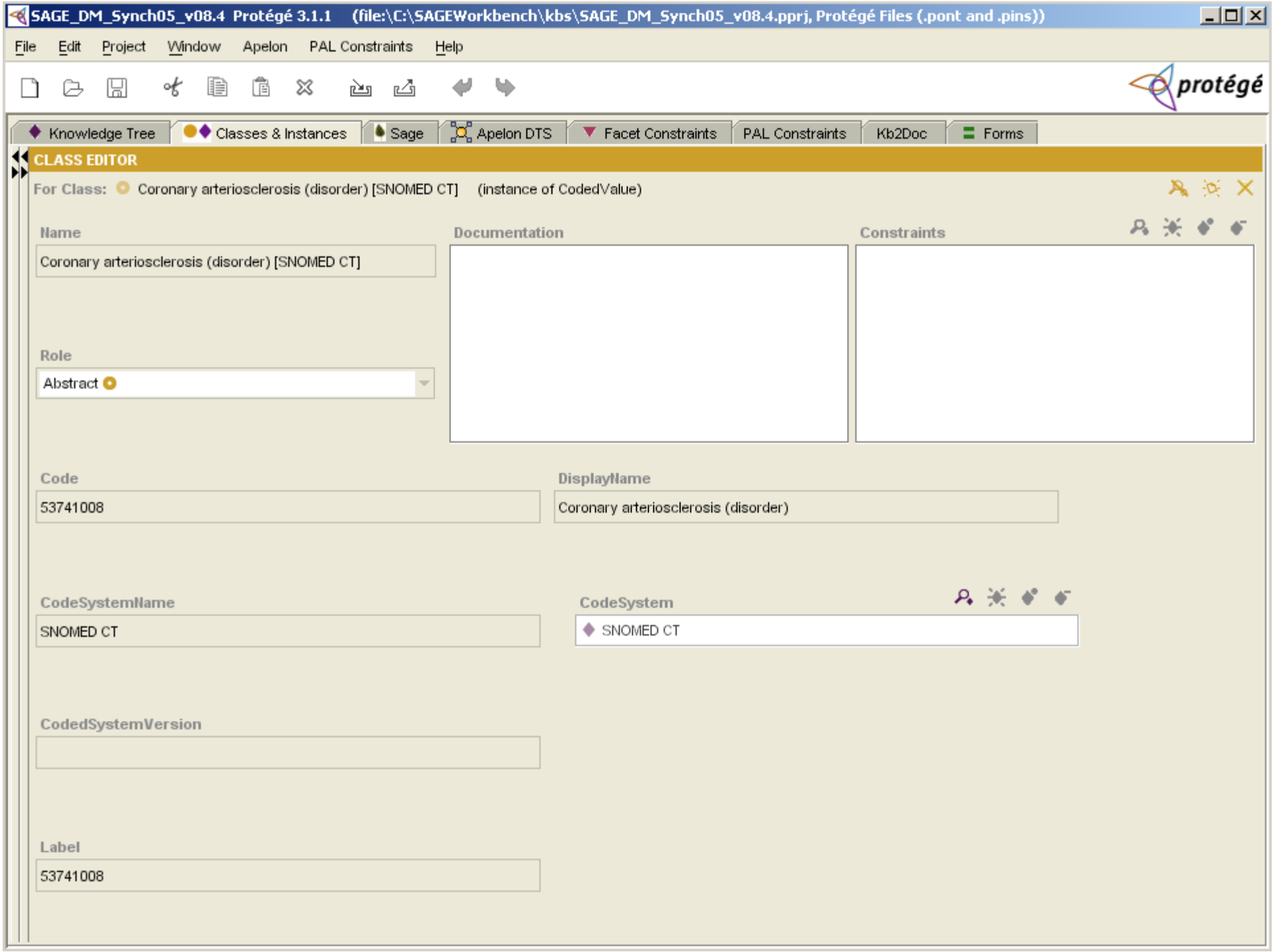
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CLASS EDITOR
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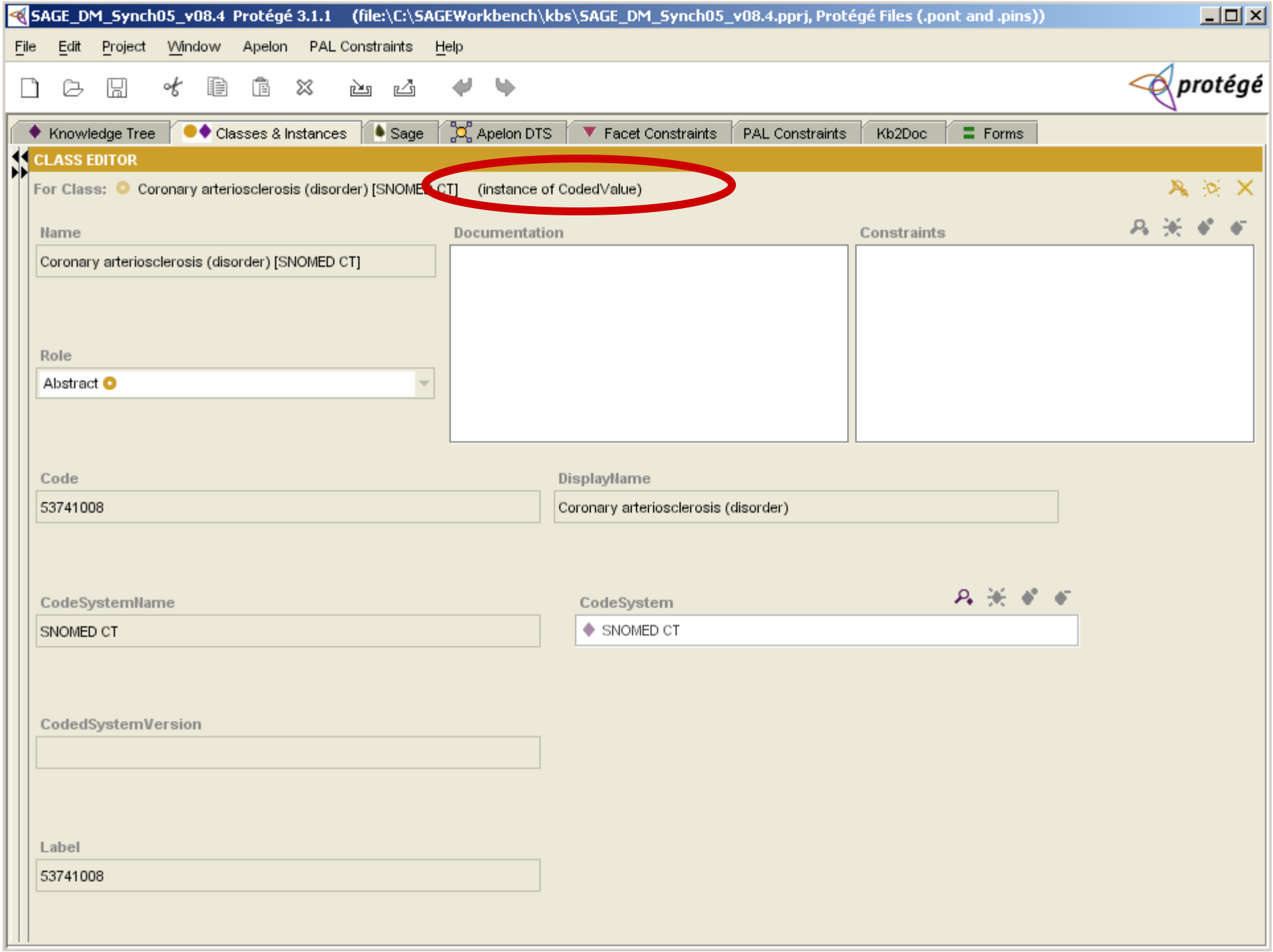
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Role
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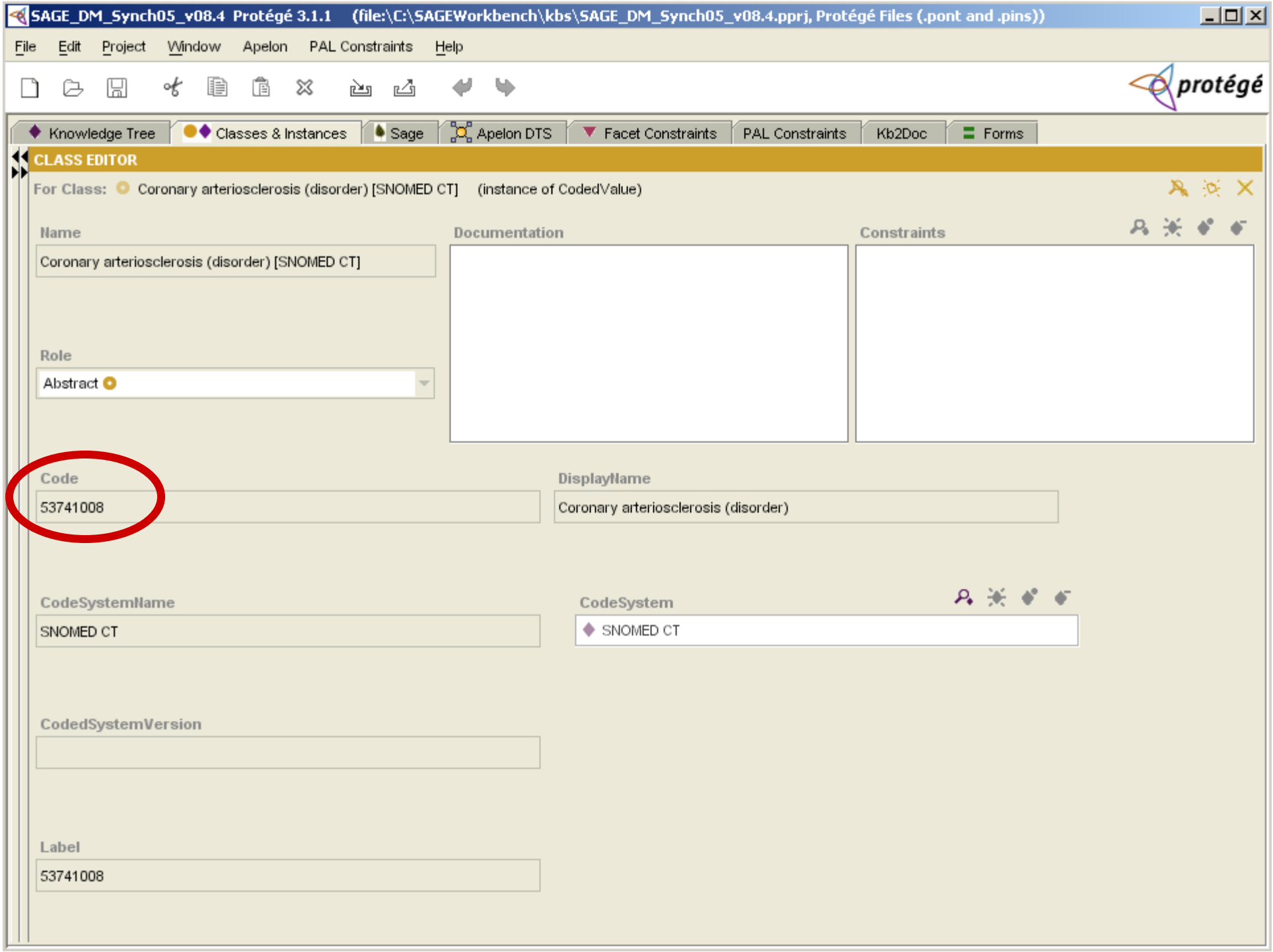
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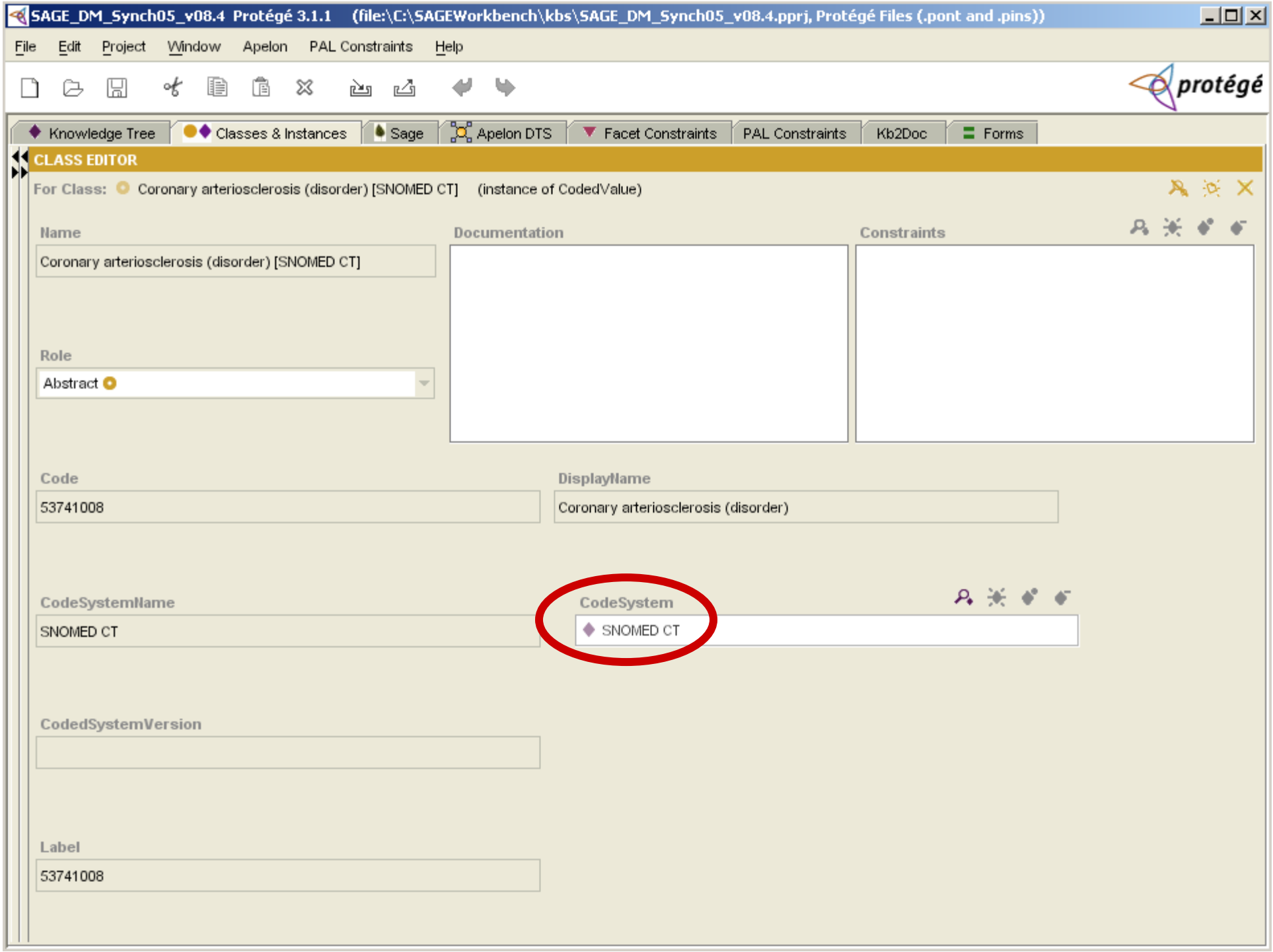
Forms
CLASS EDITOR
For Class: Coronary arteriosclerosis (disorder) [SNOMED CT] (instance of CodedValue)
Name
Coronary arteriosclerosis (disorder) [SNOMED CT]
Documentation
Constraints
Role
Abstract
Code
53741008
DisplayName
Coronary arteriosclerosis (disorder)
CodeSystemName
SNOMED CT
CodeSystem
SNOMED CT
CodedSystemVersion
Label
53741008


SAGE_DM_Synch05_v08.4 Protégé 3.1.1 (file:\C:\SAGEWorkbench\kbs\SAGE_DM_Synch05_v08.4.pprj, Protégé Files (.pont and .pins))
File Edit Project Window Apelon PAL Constraints Help
protégé
Knowledge Tree
Classes & Instances
Sage
Apelon DTS
Facet Constraints
PAL Constraints
Kb2Doc
Forms
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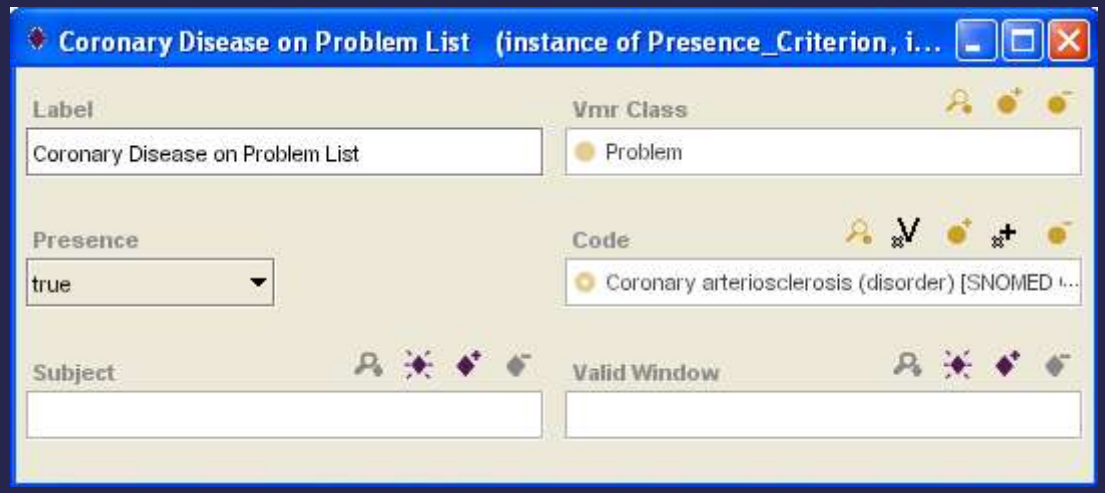
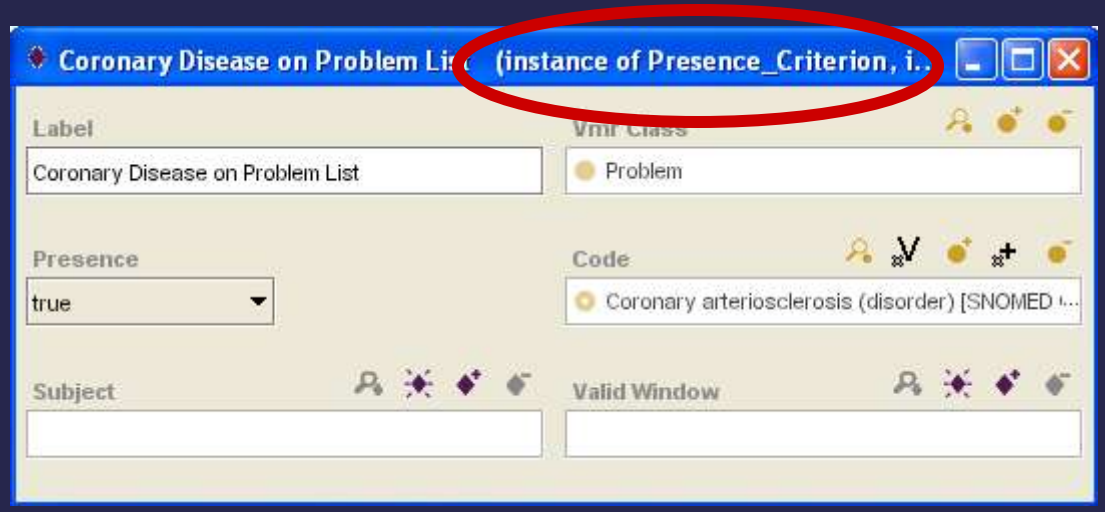

Coronary Disease on Problem List (instance of Presence_Criterion, i...
Label
Coronary Disease on Problem List
Vmr Class
Problem
Presence
true
Code
Coronary arteriosclerosis (disorder) [SNOMED
Subject
Valid Window

SAGE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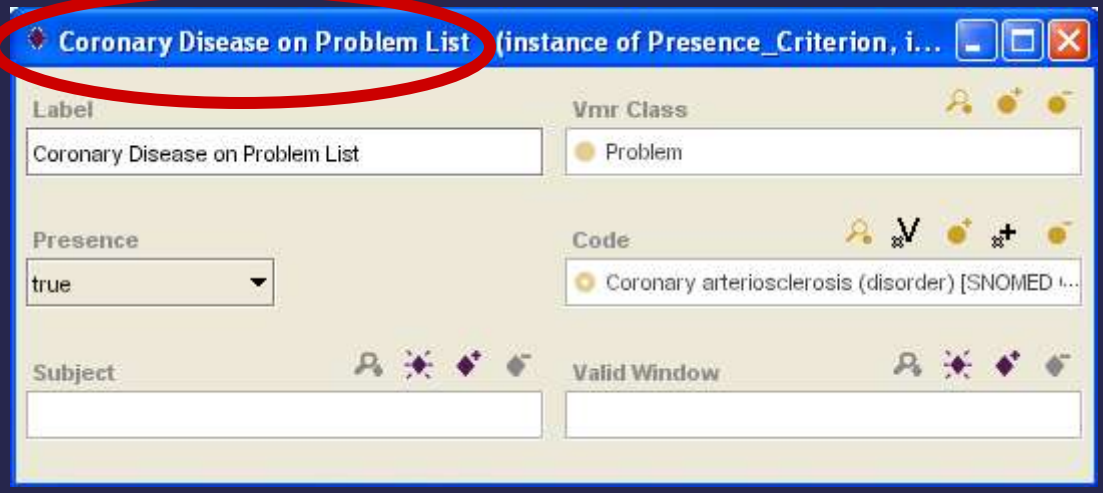
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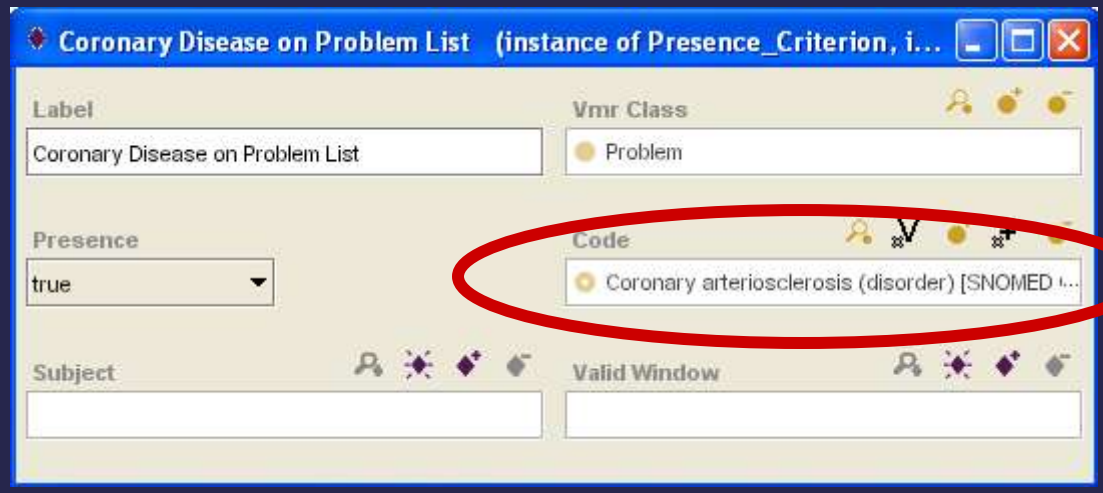
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SAGE Terminologies

- Standards
  - SNOMED CT
  - LOINC
  - NDF-RT
- Extensions
  - Concept expressions
  - Modular classification
  - Candidates for submission to terminology authorities

Concept Expressions

- Arbitrary subsets of taxonomies
- Defined with logical operators
- Novel taxonomic interpretation

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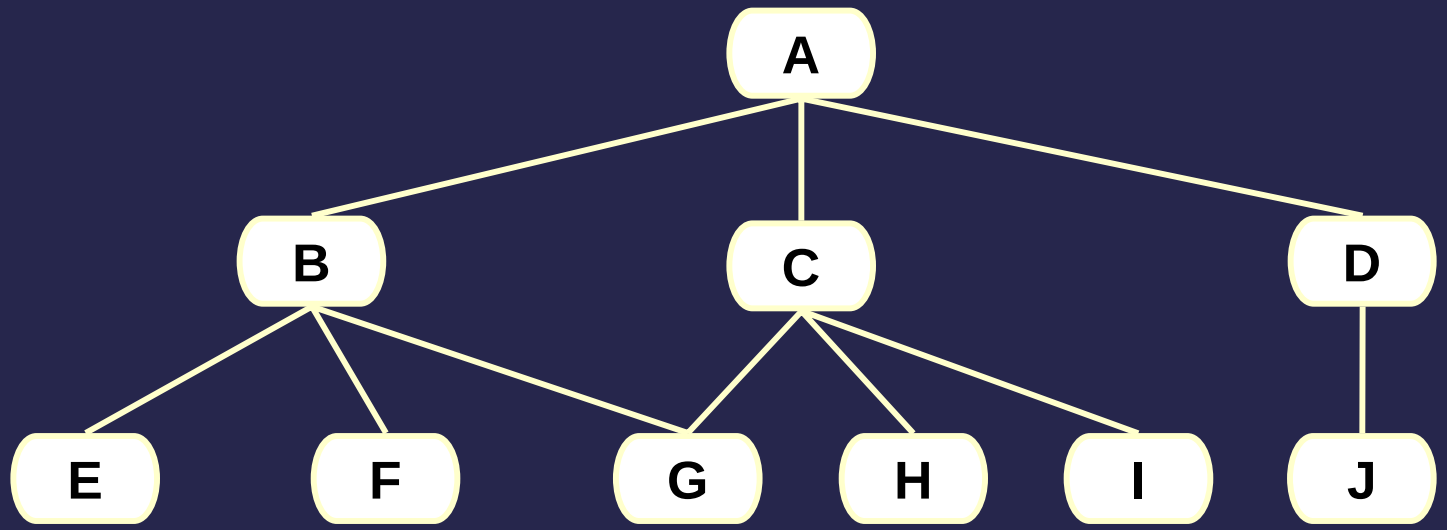

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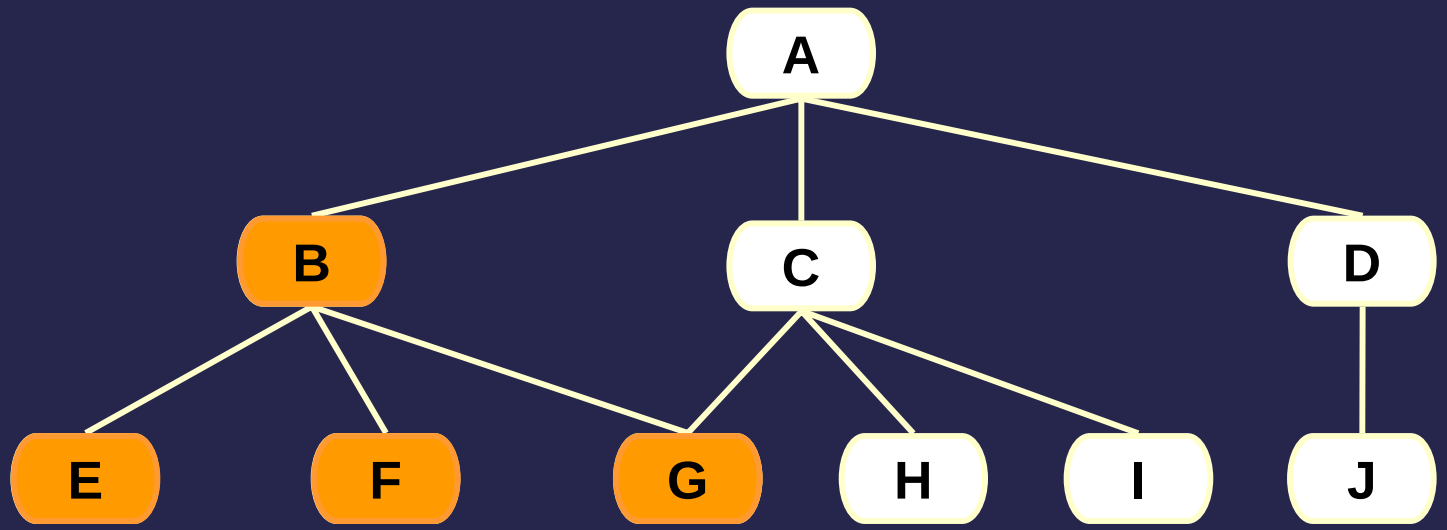

SAGE

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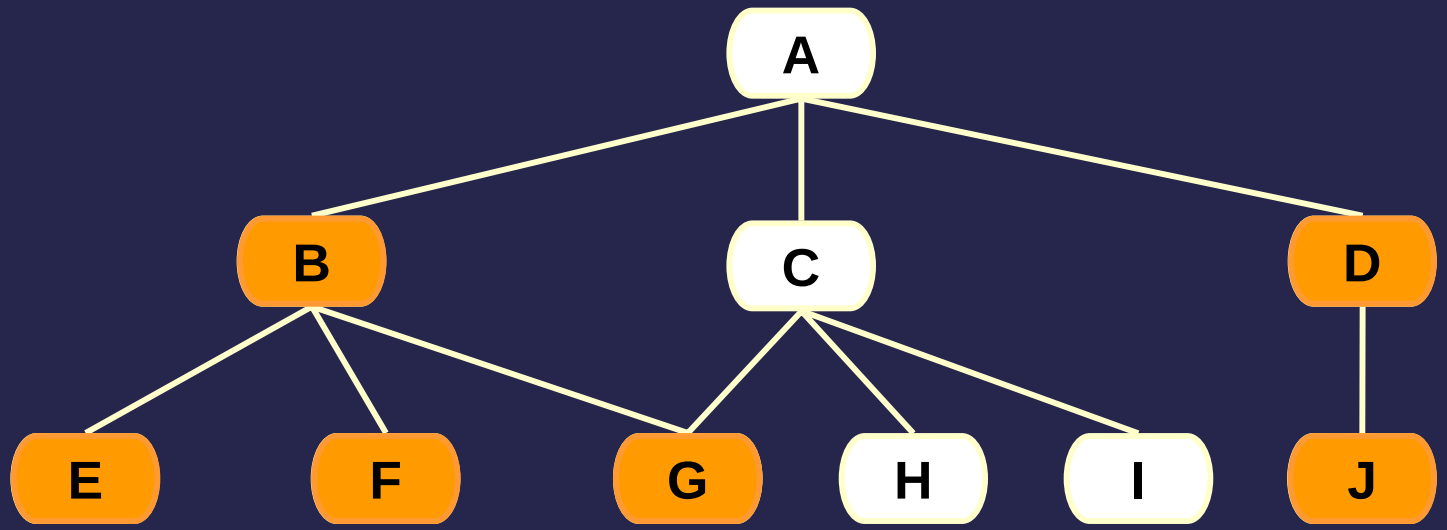

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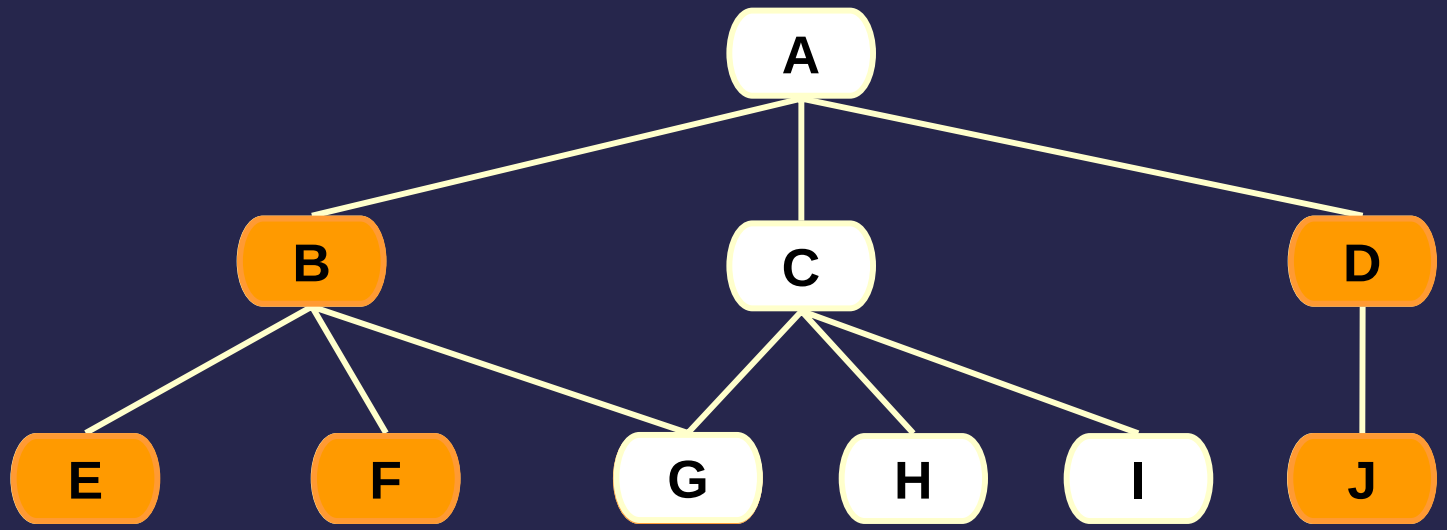
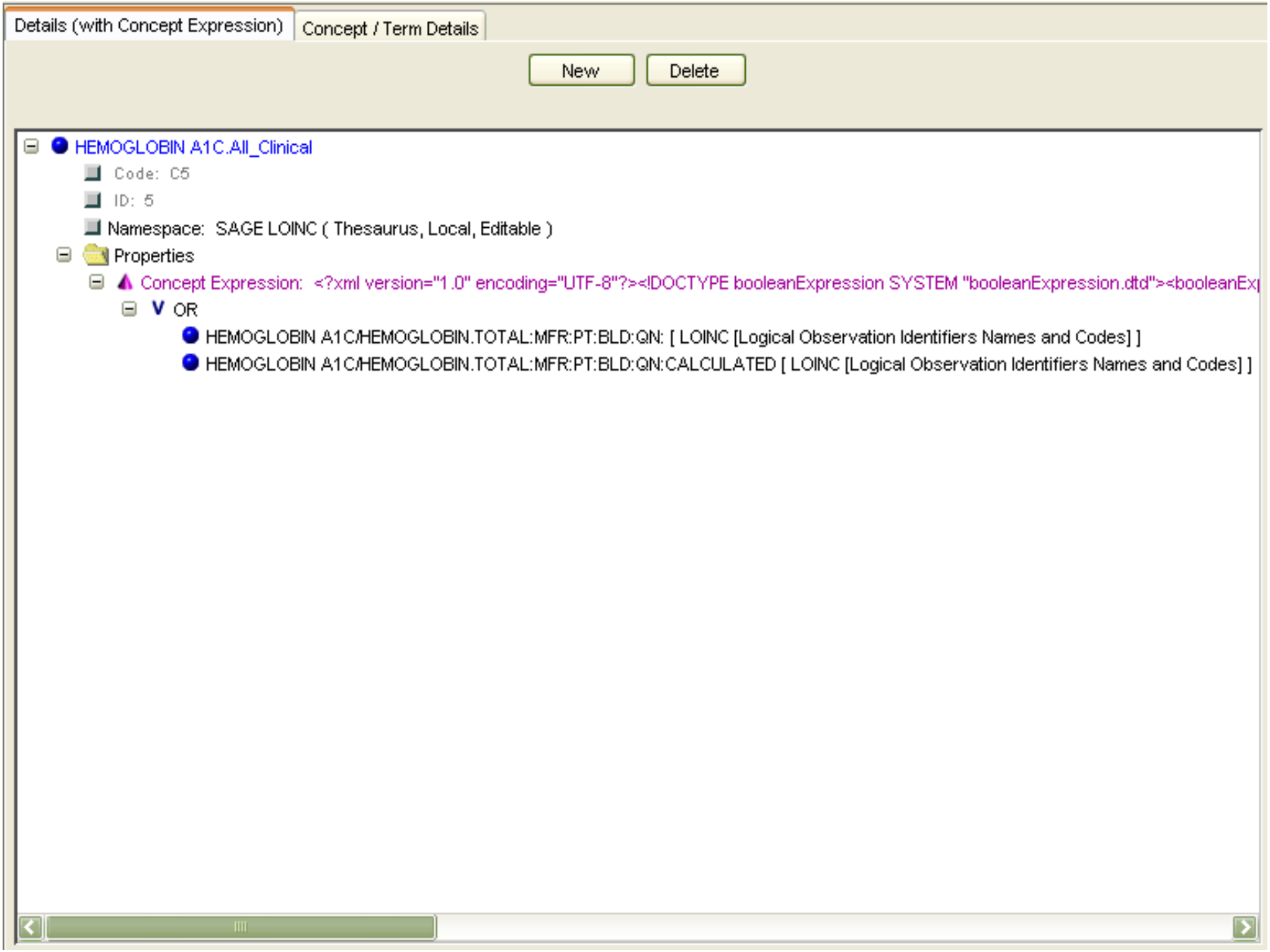


SAGE


Details (with Concept Expression)
Concept / Term Details
New
Delete
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Code: C5
ID: 5
Namespace: SAGE LOINC (Thesaurus, Local, Editable)
Properties
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OR
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HEMOGLOBIN A1C/HEMOGLOBIN.TOTAL:MFR:PT:BLD:QN:CALCULATED [LOINC [Logical Observation Identifiers Names and Codes]]

Modular Classification

- Additional concepts conforming to the SNOMED CT or NDF-RT models

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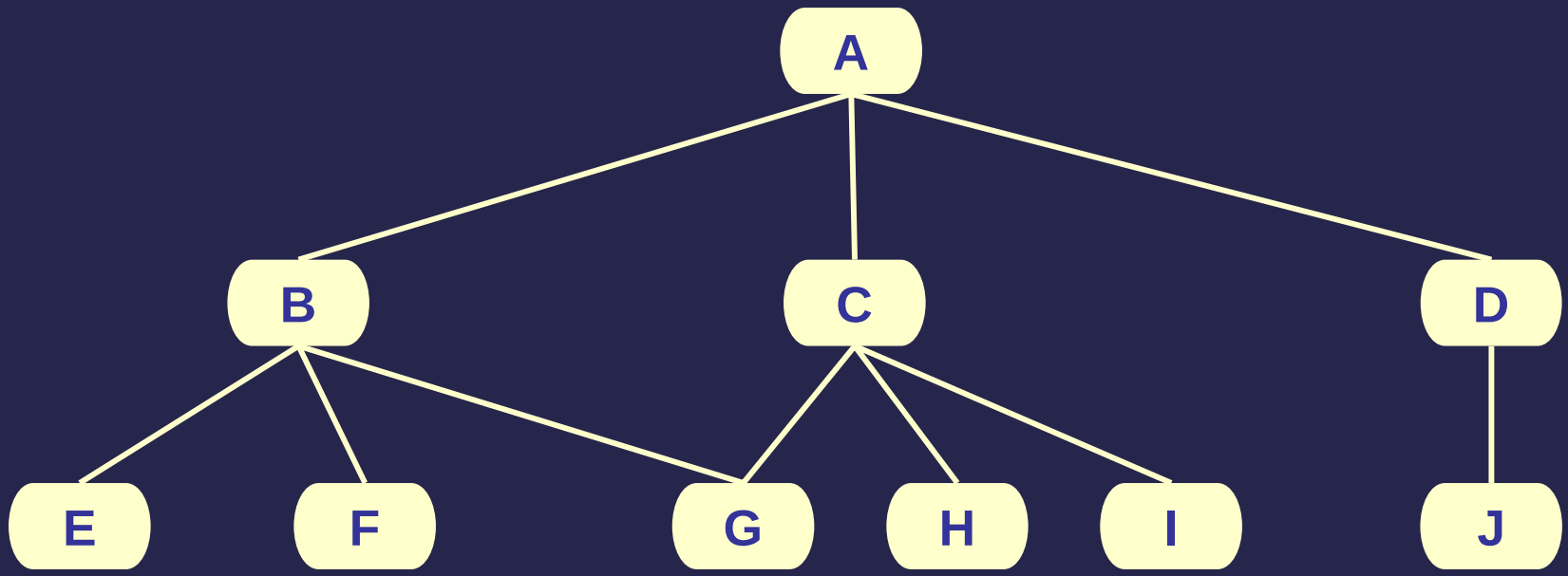

SAGE

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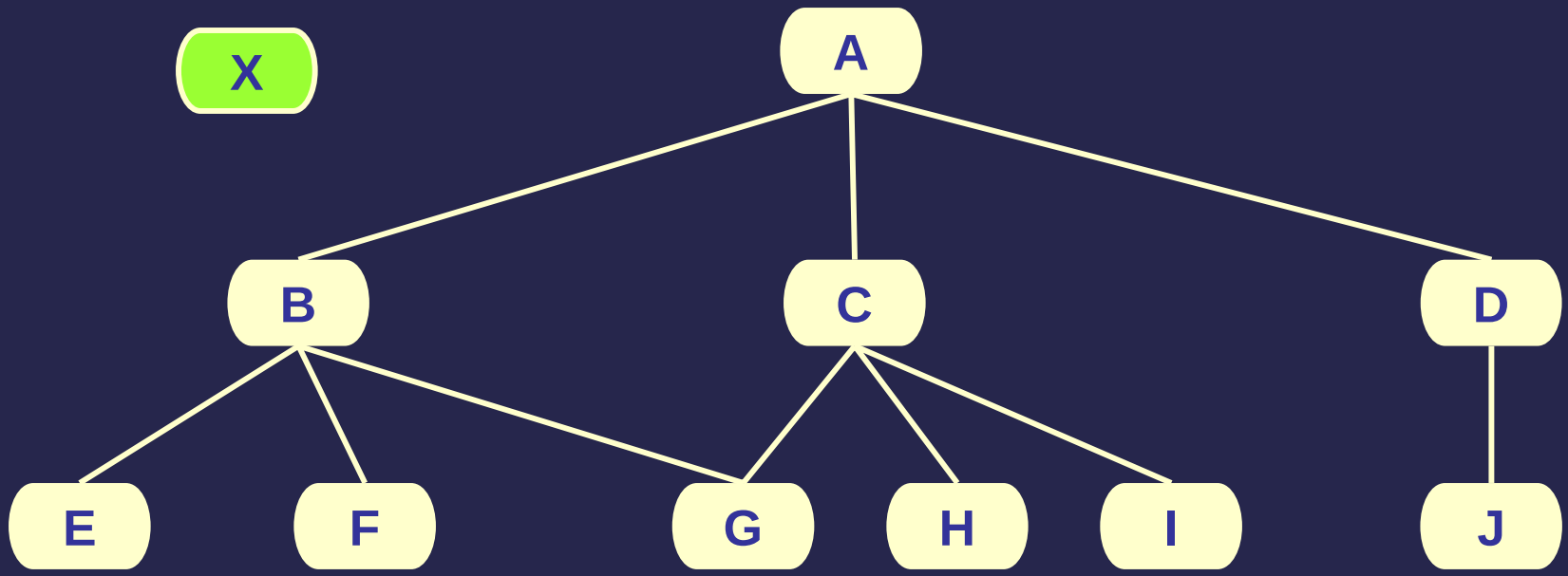

SAGE

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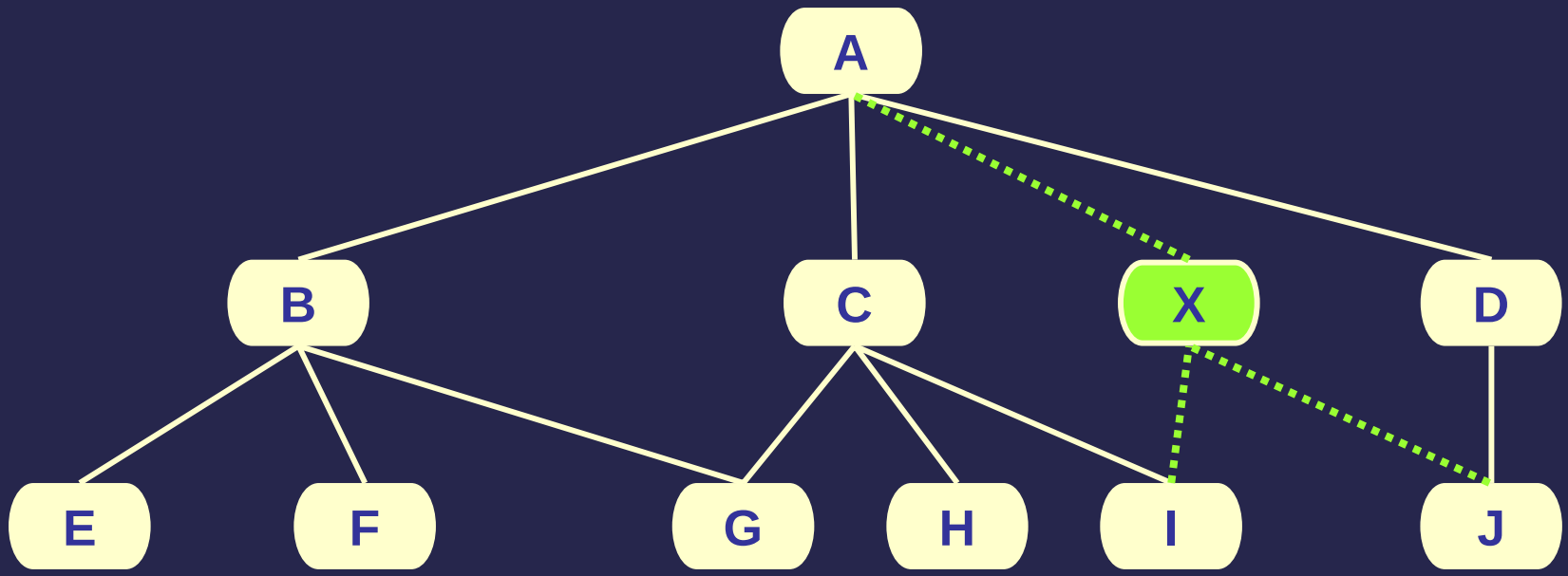
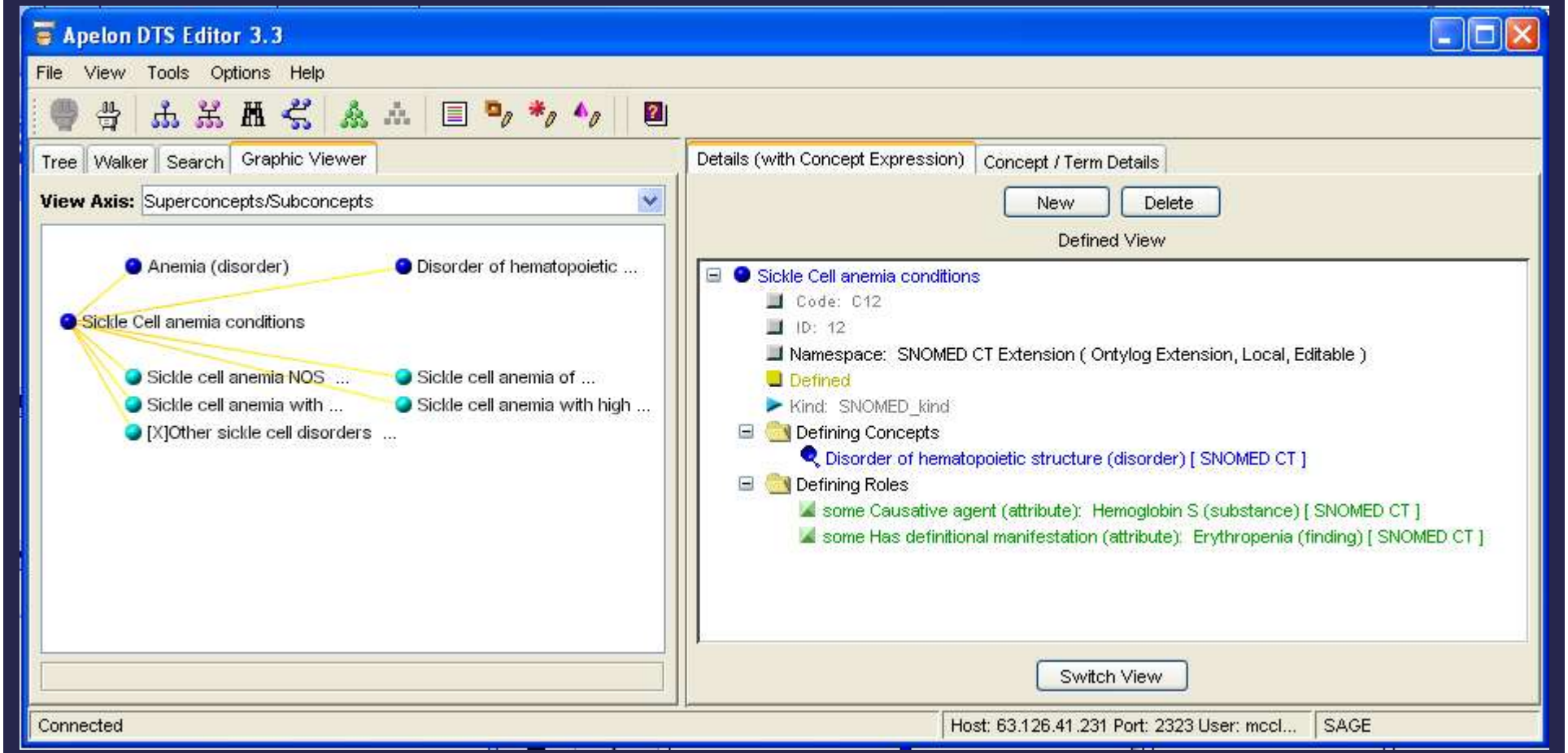


Ex: Modular Extension Concept



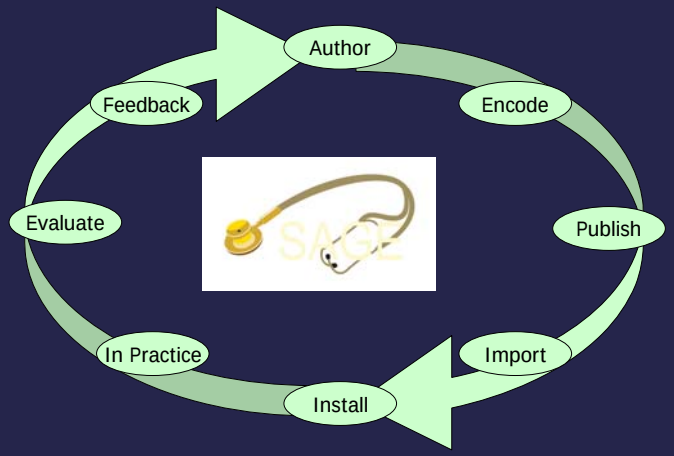
Runtime Execution with Terminologies

- Common Terminology Services (CTS)
  - ISO / ANSI / HL7 standard API for DTS
- Serves the guideline engine
- Compares concepts in a guideline with entries in medical records (mediated by the VMR)
- Subsumption testing
  - Is *maternal diabetes mellitus* a type of *diabetes?*

Interoperable Guideline Deployment

- SAGE Guideline Execution Infrastructure
- Interoperable deployment to host CIS platforms

Robert Abarbanel, MD, Ph.D.
GE Healthcare, Seattle



SAGE Guideline Execution Architecture

Portable SAGE Execution Engine

Event Listener

Event Notifications

Clinical Information System

VMR Services Action Interface

{ }

VMR Service calls

Action Service calls

Terminology Functions

Other Servers

Terminology Server

Standards-based I/F based on web services

CIS-specific implementation of services

SAGE

SAGE Guideline Execution Architecture

What is portable? ✓

Portable SAGE Execution Engine ✓

Event Listener ✓

Event Notifications

Clinical Information System

VMR Services Action Interface ✓ { }

VMR Service calls

Action Service calls

Terminology Functions

Other Servers ✓

Terminology Server ✓

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SAGE

SAGE Guideline Execution Architecture

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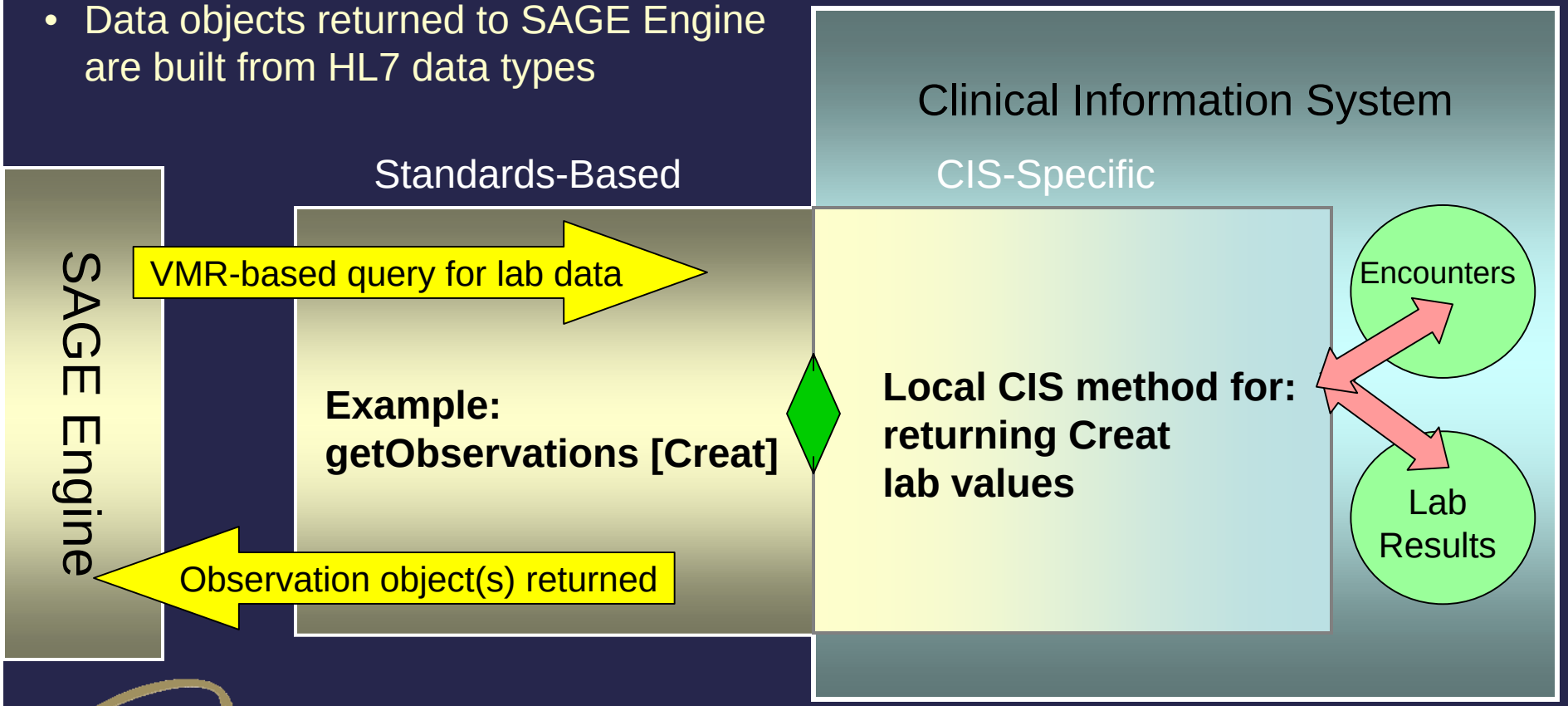
SAGE

VMR Services Interface

- In the guideline model, patient data concepts are represented using VMR classes
- Queries for patient data are represented using standard VMR-based methods
- Patient data queries are processed via VMR Service web service
- Generic methods are “mapped” to CIS-specific methods
- Data objects returned to SAGE Engine are built from HL7 data types



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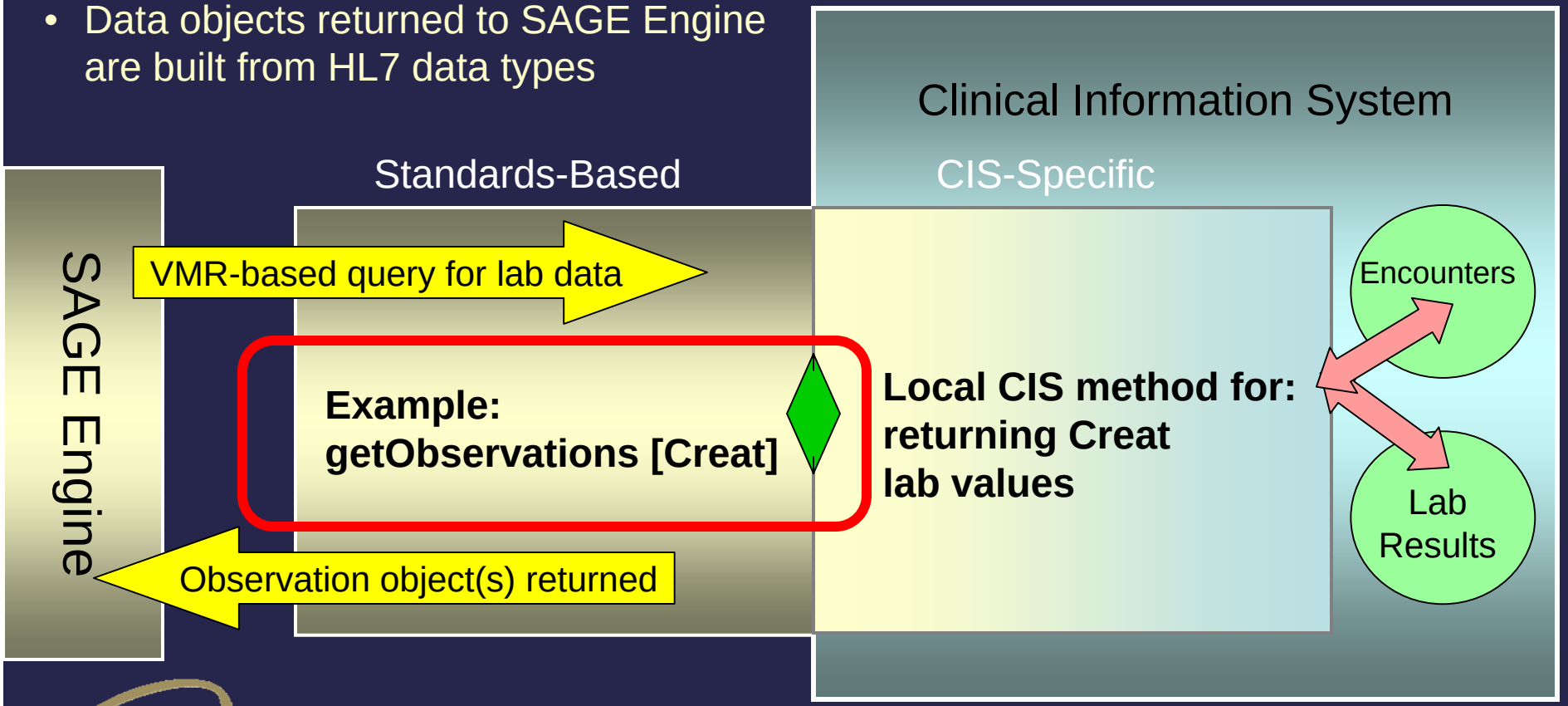

VMR Services Interface

getAppointments

getAlerts

getProcedures

getProblems

getSubstanceAdministrations

getAgents

getReferrals

getAdverseReactions

getMedicationOrders

getVMROrders

getEncounters

getGoals

```
getXX ( patient_id, [ filters ] );
```

VMR Services Interface

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getProcedures

getProblems

getSubstanceAdministrations

getAgents

getReferrals

getAdverseReactions

getMedica[illegible]Orders

getVM[illegible]

getEn[illegible]

getGoal[illegible]

where,
when,
who,
…

getXX (patient_id, [filters]);

HL7 Standard for Order Sets has multiple layers of use…

- Publish and Distribute: Authoring, maintenance and dissemination by professional standards organizations
  - versions, editing, indexing, eligibility
- Import: Deployment of order set content into vendor EHR
  - display groups, full text orders, static alerts
- Present: Organization and delivery of order set content for maximum clinical usefulness
  - sequencing, selection groups, pre-selection
- Manage as knowledge: Employment of XML order sets within execution environment for guideline decision support
  - dynamic alerts, session coding, order selection

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Community Acquired Pneumonia: Hospital Admission, General Inpatient (Adult)

ALL of these are required:

- Admission Discharge Transfer
- Consults
- Vital Signs Assessment
- Diet
- Activity
- Laboratory
- Ancillary
- Treatments
- Education
- IV Fluids
- Medication

Submit

- Medication

Choose among these:

- ☐ Administer first dose of antibiotics within 4 hours of admissi
- ☐ ▶ No Pseudomonas risk factor identified
- ☑ ▶ Pseudomonas risk factors: structural lung dis
- ☐ ▶ Suspected Legionella Pneumonia
- ☐ ▶ Suspected Aspiration Pneumonia
- ☐ ▶ Antipyretic Agents, Adult
- ☐ ▶ Bronchodilator
- ☐ ▶ Additional medication orders

SAGE

- ☑ ▼ Pseudomonas risk factors: structural lung disease, chronic steroid > 10 g/day, malnutrition

  Choose among these:

  - ☑ ▼ Choice 1

    Both of these are required:

    - ▼ Cephalosporin, Penicillins, and/or beta-lactamase inhibitor

      Choose ONE of these:

      1. ○ Cefipime 2 grams IV q8h
      2. ◉ Piperacillin/tazobactam 4.5 grams IV q6h
      3. ○ Imipenem 500mg IV q6h

    - Azithromycin 500 mg IV q day (infuse over 1 hour)

  - ☐ ▼ Choice 2

    Choose ONE of these:

    1. ○ Levofloxacin 500mg qd
    2. ○ ▼ Tobramycin

       Both of these are required:

       - Tobramycin IV 10mg 2.5mg/kg q6h
       - Peak and Trough Tobramycin levels at 3rd dose; pharmakinetics consult

HL7 Standard for Order Sets Supports Presentation

```
<title>Code Status</title>
<boolean_connector>XOR</boolean_connector>
<set>
  <boc id="BOC_3">
    <condition>false</condition>
    <title>Main Code Status</title>
    <boolean_connector>XOR</boolean_connector>
    <set>
      <Order_Item id="OI_8">
        <condition>true</condition>
        <title>Patient is full code</title>
        <Order full_text_order="Patient is full code.">
          <ObservationOrder>
            <code>365870005|SNOMED CT</code>
            <!-- Z0009 = Patient is full code -->
          </ObservationOrder>
        </Order>
      </Order_Item>
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        <condition>false</condition>
        <title>Do not intubate</title>
        <Order full_text_order="Do not intubate.">
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            <code>304253006|SNOMED CT</code>
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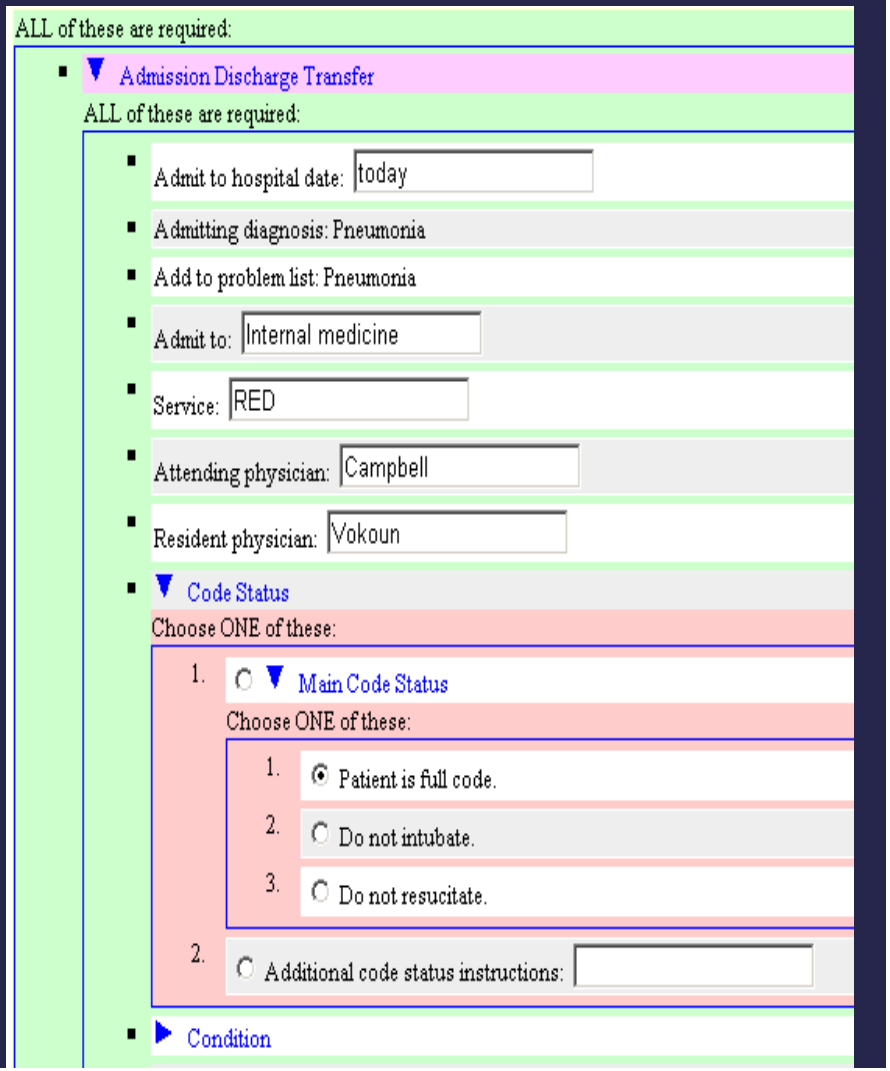

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XOR

XOR

ALL of these are required:

- Admission Discharge Transfer

  ALL of these are required:

  - Admit to hospital date: today
  - Admitting diagnosis: Pneumonia
  - Add to problem list: Pneumonia
  - Admit to: Internal medicine
  - Service: RED
  - Attending physician: Campbell
  - Resident physician: Vokoun
  - Code Status

    Choose ONE of these:

    1. Main Code Status

       Choose ONE of these:

       1. (•) Patient is full code.
       2. ( ) Do not intubate.
       3. ( ) Do not resucitate.

    2. ( ) Additional code status instructions:
  - Condition

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pre-select

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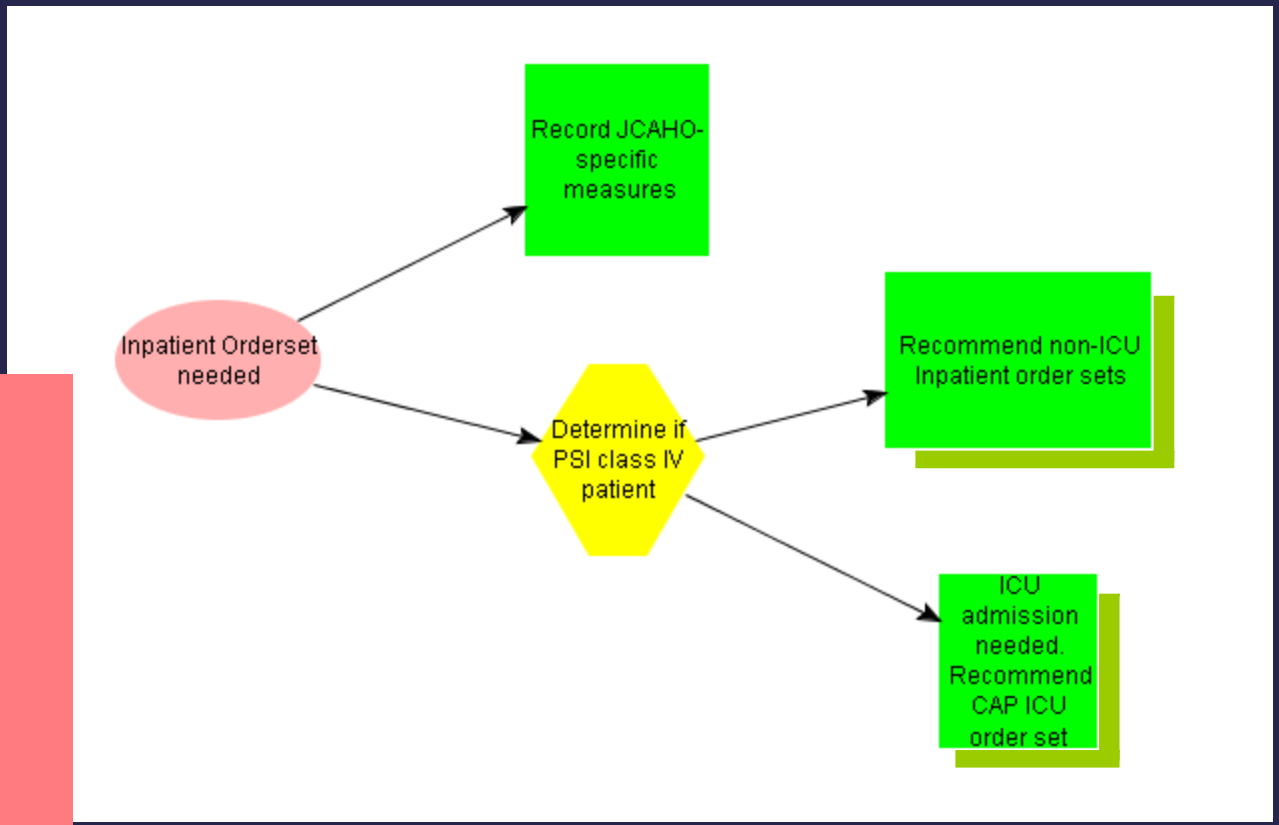
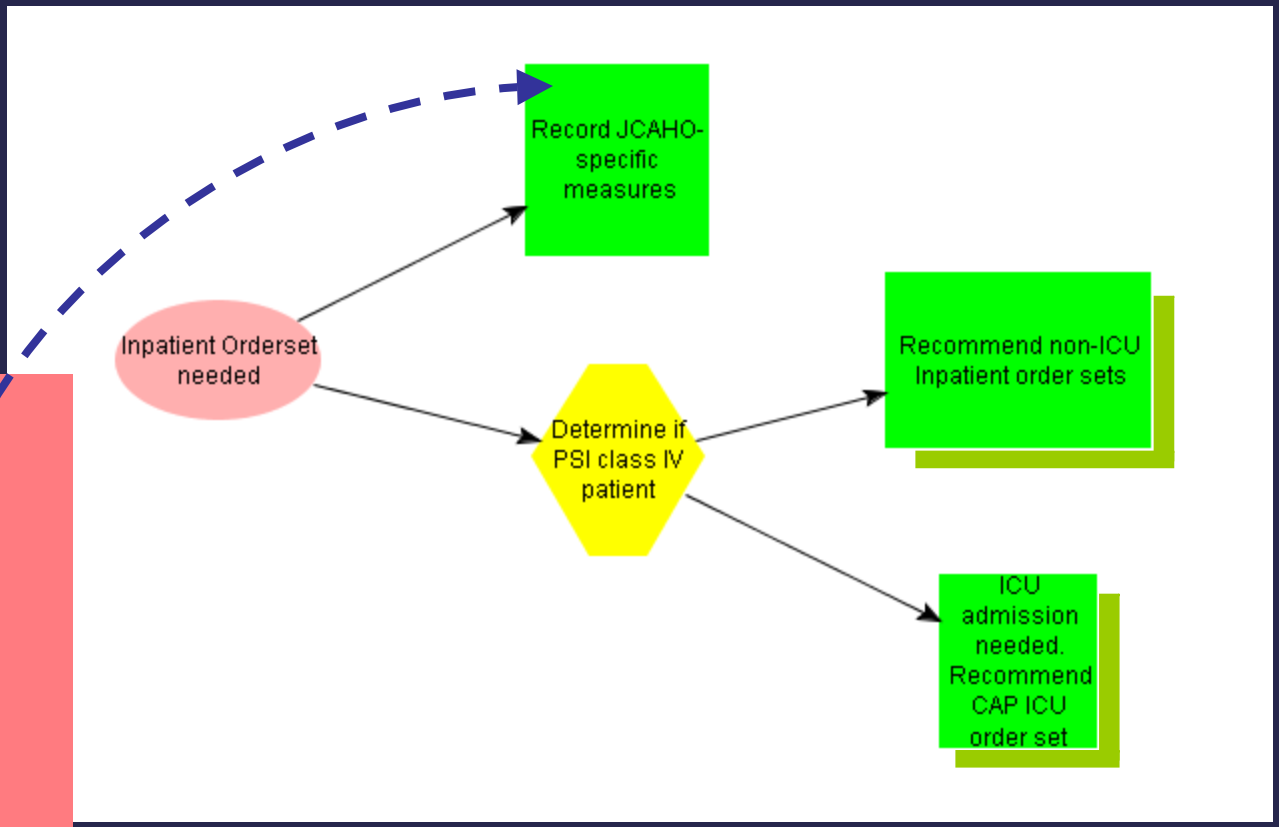
Inpatient logic for patient with class IV pneumonia



Two actions to be taken:

1) JCAHO measures,
2) Admission orders.

Inpatient logic for patient with class IV pneumonia



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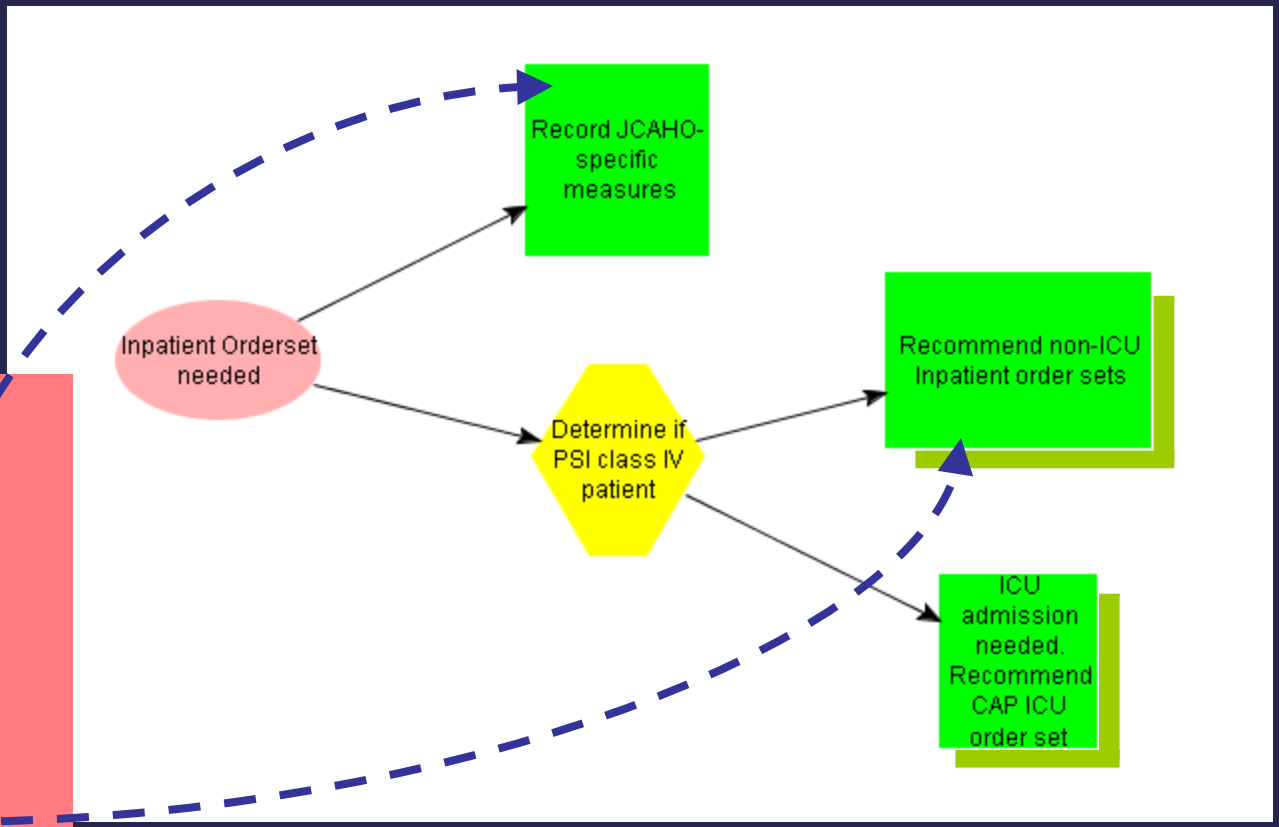

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SAGE

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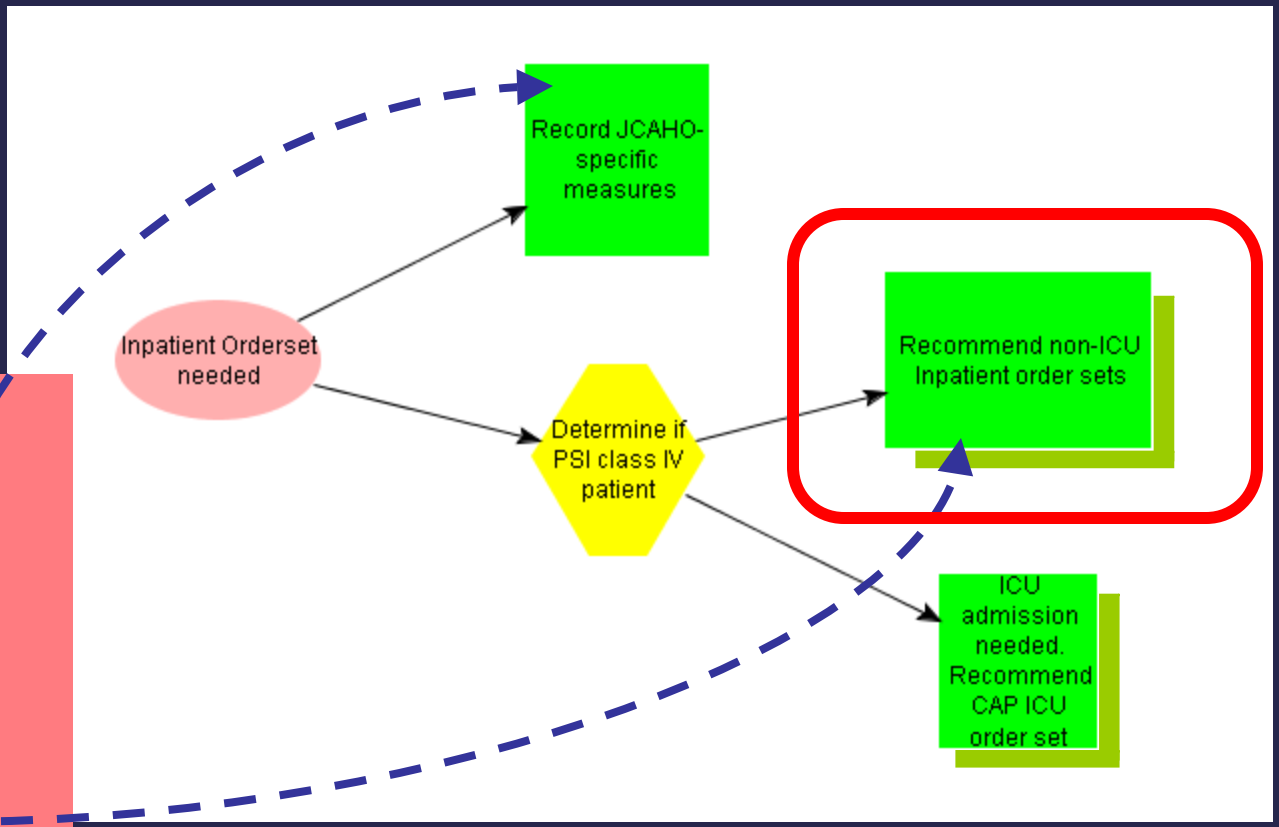

Two actions to be taken:

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Medications for Non-ICU CAP Admission

▼ Medication

Choose among these:

- ☐ Administer first dose of antibiotics within 4 hours of admission
- ☑ ▼ No recent antibiotic therapy — **There was no evidence of recent Abx therapy, please confirm.**

Choose ONE of these:

1. ◉ ▼ Macrolid plus Beta-lactam

   Both of these are required:

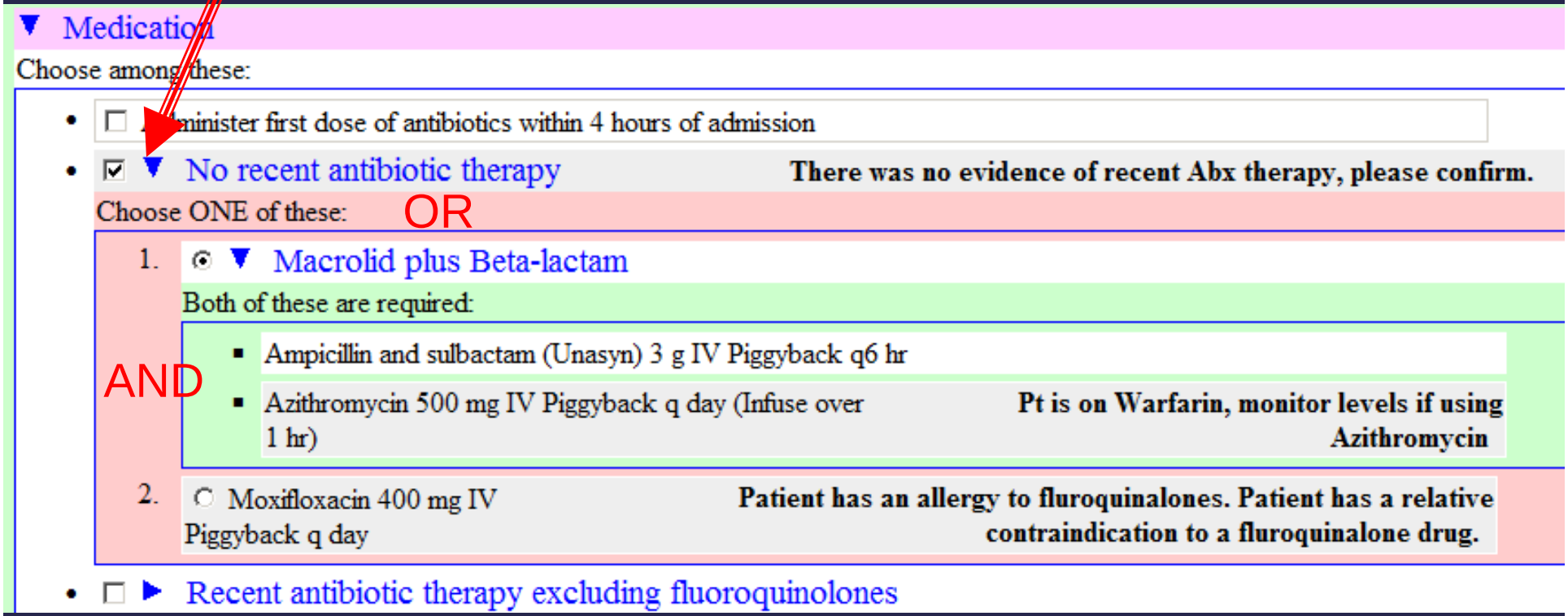
   - Ampicillin and sulbactam (Unasyn) 3 g IV Piggyback q6 hr
   - Azithromycin 500 mg IV Piggyback q day (Infuse over 1 hr) — **Pt is on Warfarin, monitor levels if using Azithromycin**

2. ○ Moxifloxacin 400 mg IV Piggyback q day — **Patient has an allergy to fluroquinalones. Patient has a relative contraindication to a fluroquinalone drug.**

- ☐ ▶ Recent antibiotic therapy excluding fluoroquinolones

Medications for Non-ICU CAP Admission

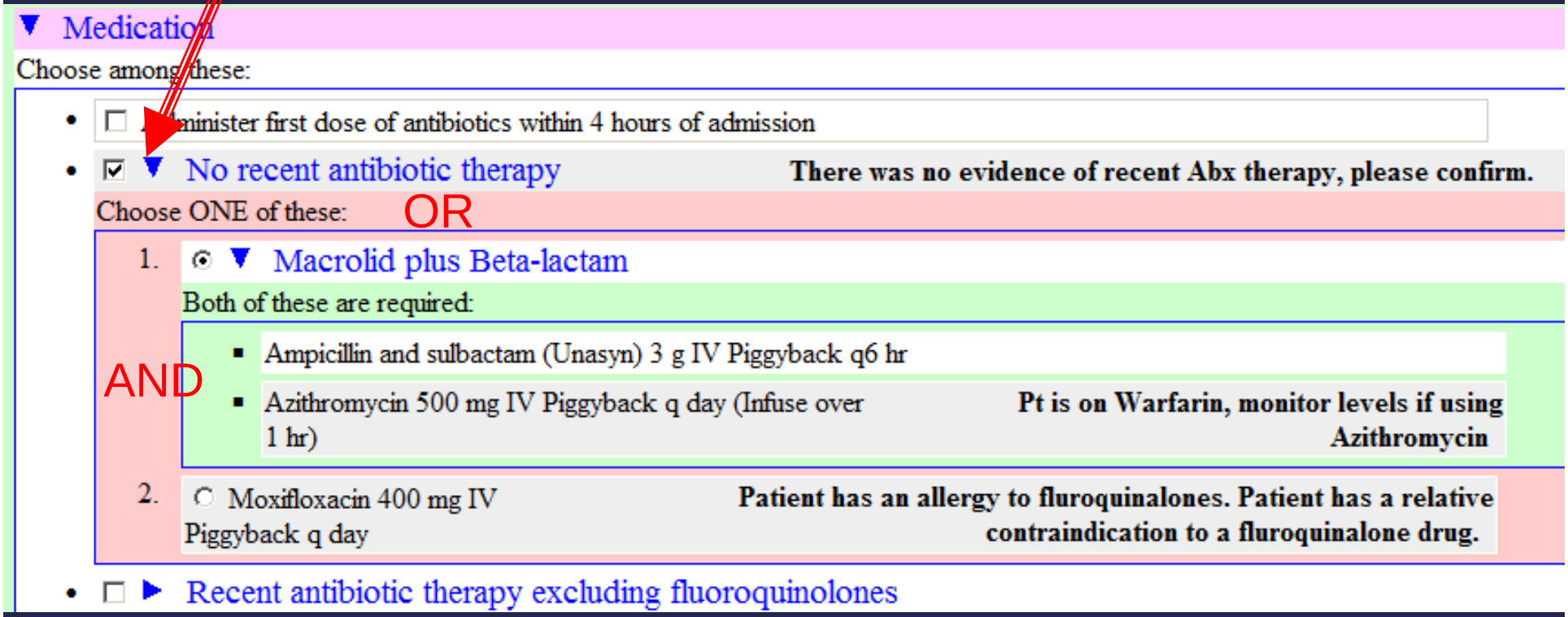
Pre-selected by SAGE



Medications for Non-ICU CAP Admission

Pre-selected by SAGE

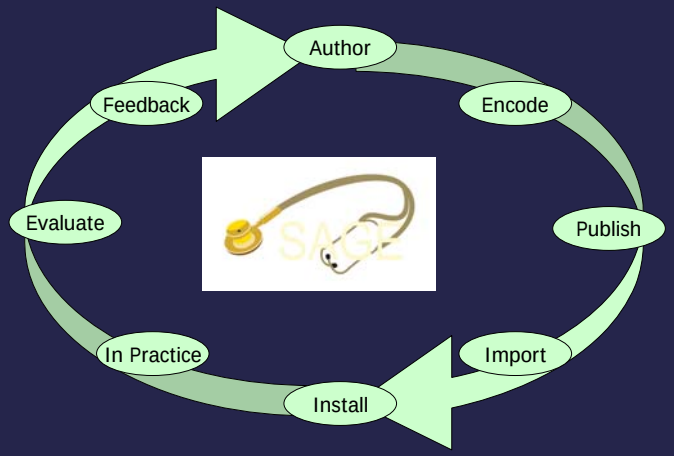
SAGE computed annotations:



Installing Computable Guidelines

- Installation of executable guideline content
- Presenting guideline recommendation to clinicians

Mark Nyman, MD
Mayo Clinic, Rochester



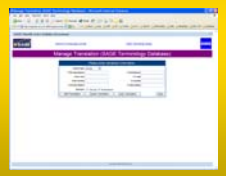
Localizing a Standards Based Encoded Guideline

Download Guideline

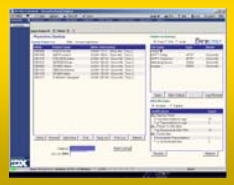
Medical Staff Review Guideline

Edit Guideline for Local Conditions

Map Standard to Local Terminologies



Activate Guideline



SAGE

Medical Staff Review Guideline

Guideline Review

- Implementing guideline-driven decision support into local care-delivery organizations requires *much more* than just technology.
  - Must be integrated with local care-delivery environment, clinical practice, and institutional culture.
  - Typically requires review of care-team communications and work flow, potential re-engineering of care processes, etc.

SAGE

Medical Staff Review Guideline

Guideline Review

Medical Staff Review Guideline

Guideline Review

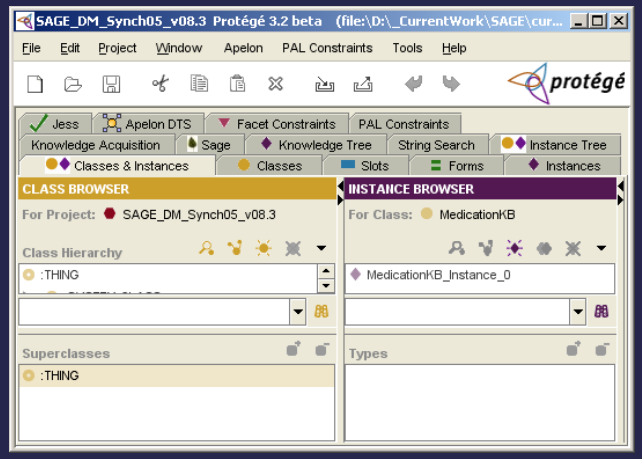
Protégé Workbench

Document-Oriented View

Medical Staff Review Guideline

Guideline Review

Protégé Workbench

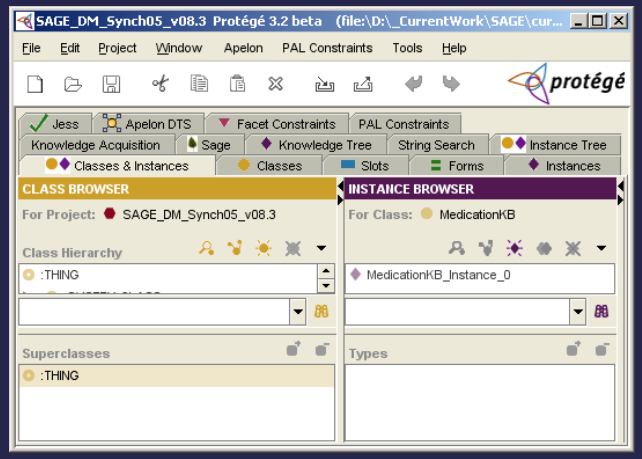


Document-Oriented View

Medical Staff Review Guideline

Guideline Review

Protégé Workbench



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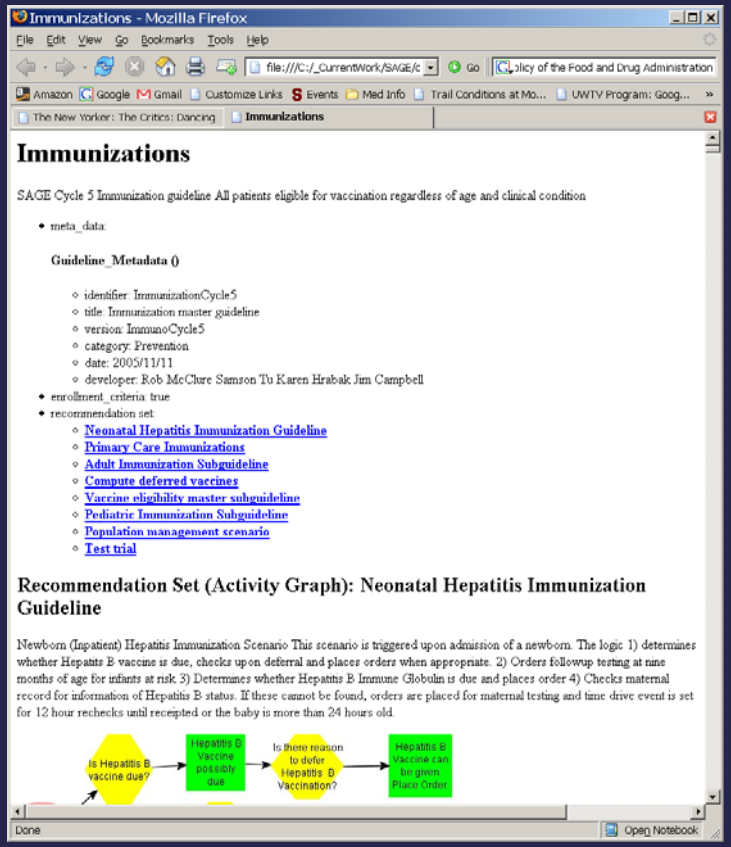

SAGE

Medical Staff Review Guideline

Guideline Review

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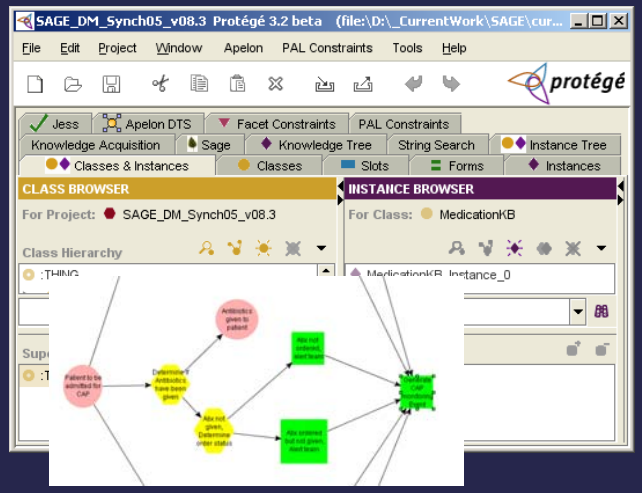

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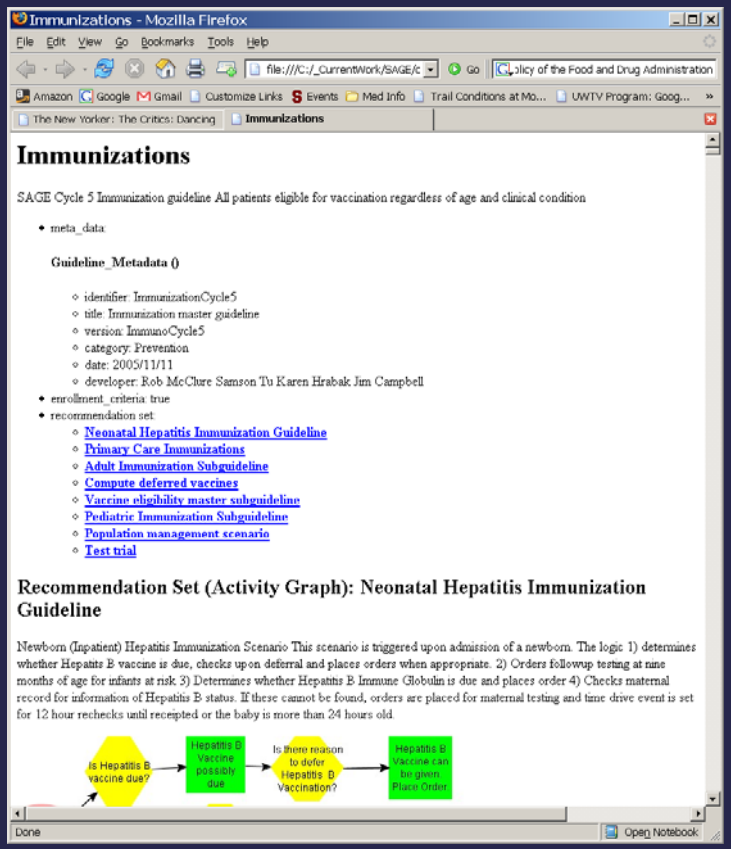

SAGE

Medical Staff Review Guideline

Guideline Review

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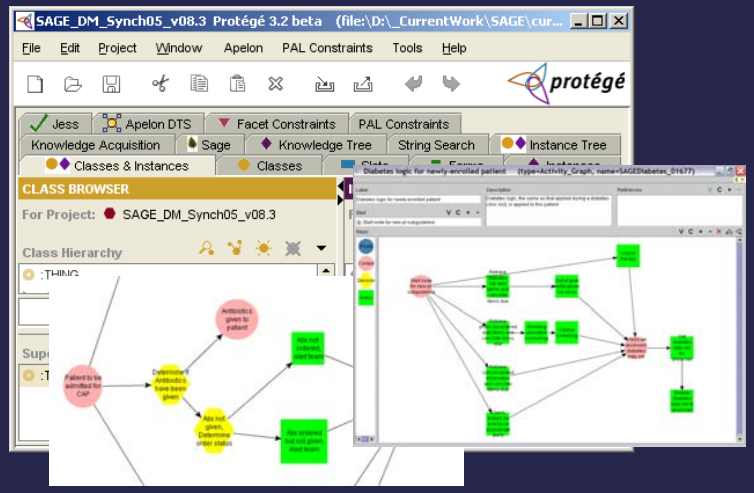

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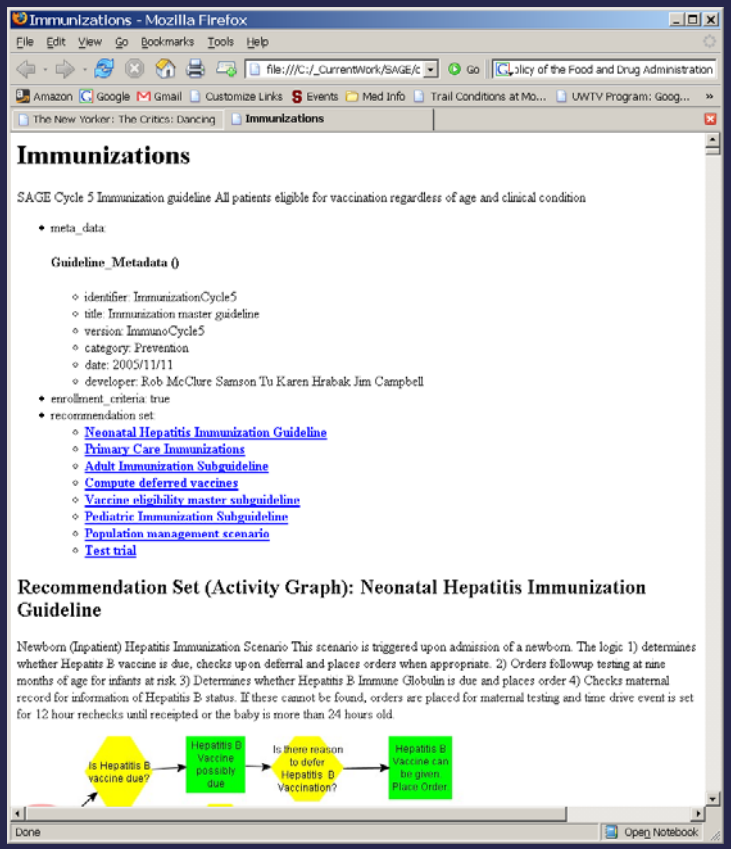

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Medical Staff Review Guideline

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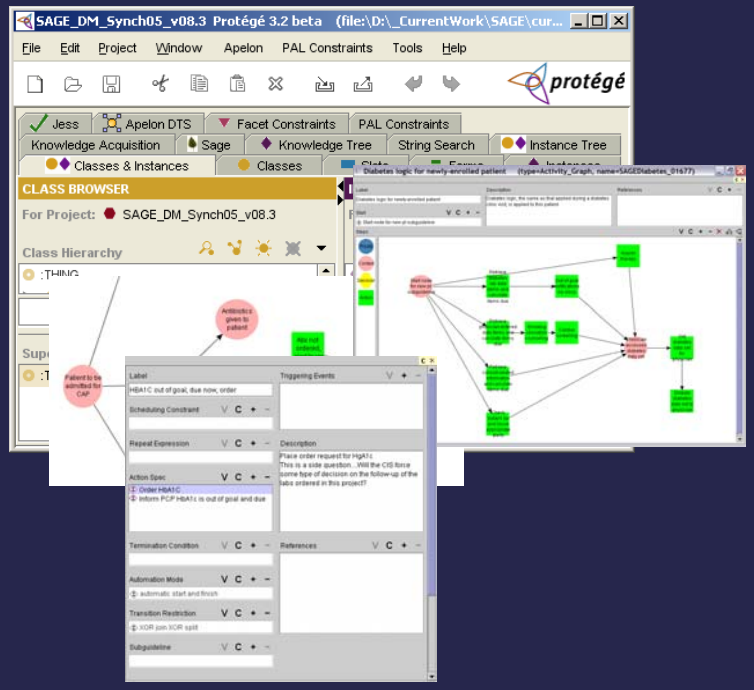

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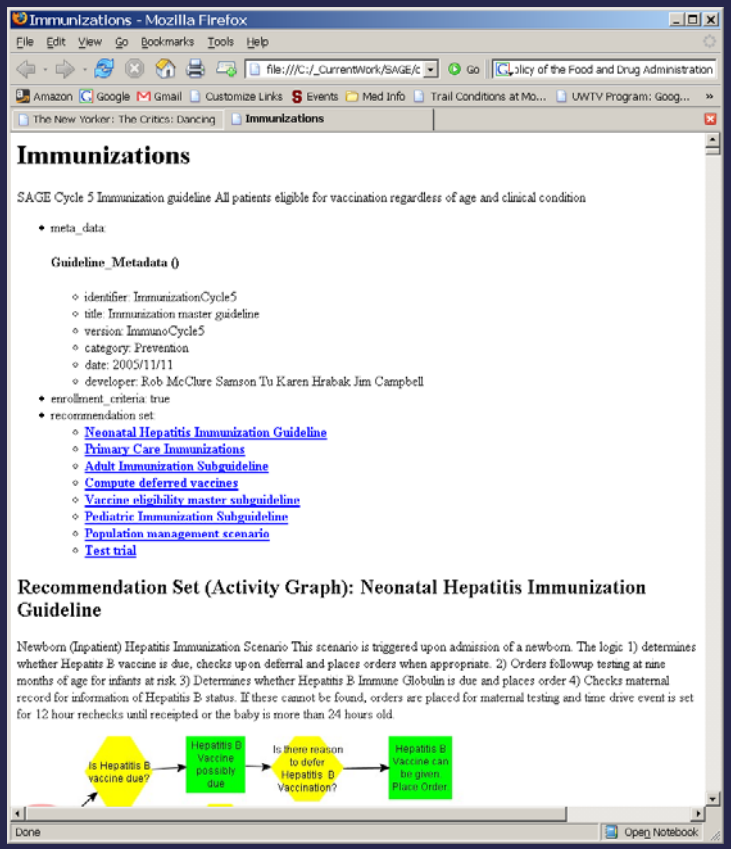

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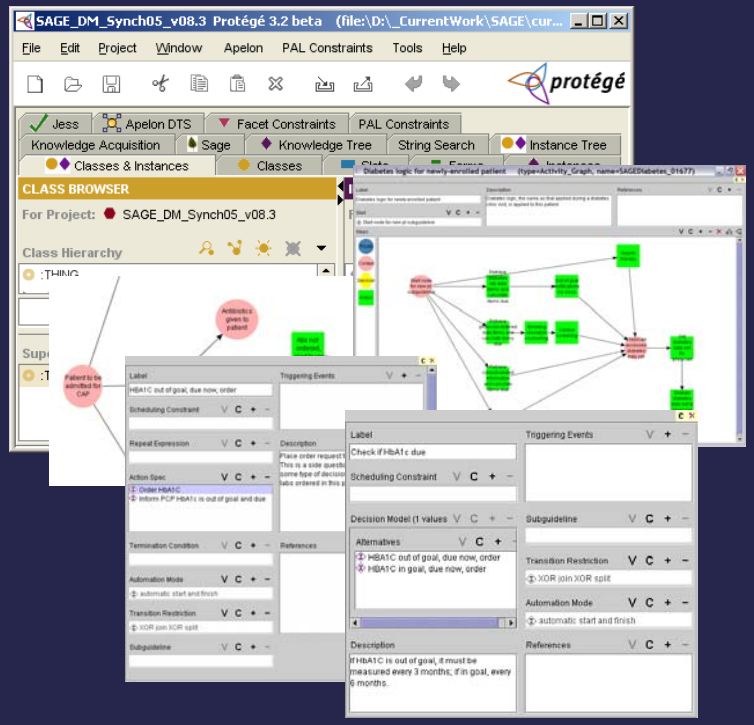

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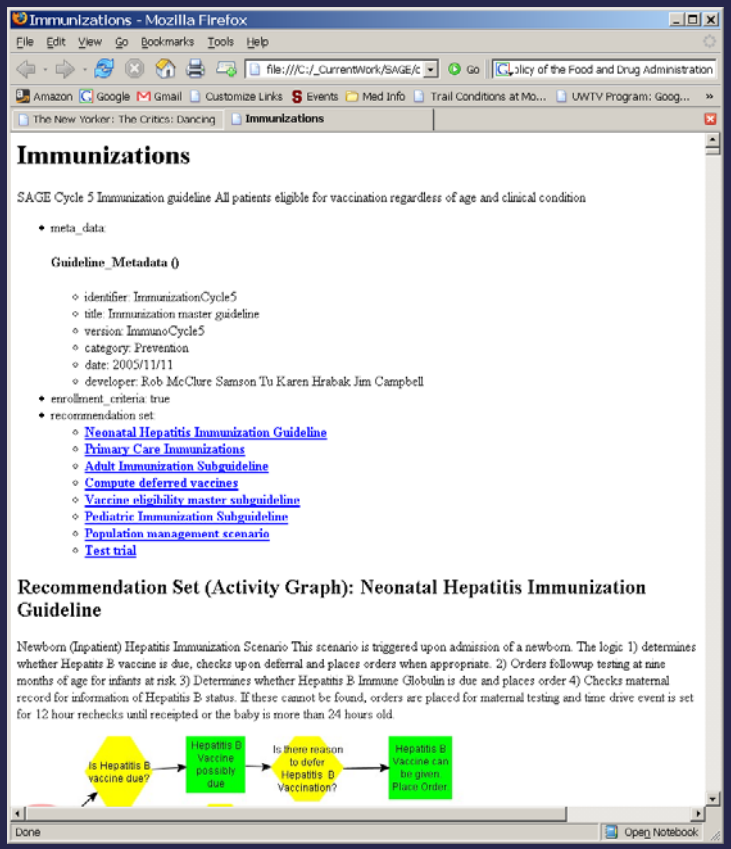

SAGE

Edit Guideline for Local Conditions

Guideline Localization

Edit Guideline for Local Conditions

Guideline Localization

- Local “edits” to to guideline content might include:
    - Minor changes (thresholds, formulary, etc.)

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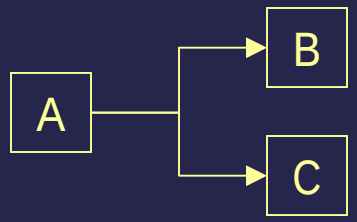
Generic Guideline

Do A, then B, then C

Local Care Workflow



Do A, then B and C in parallel

SAGE

Edit Guideline for Local Conditions

Guideline Localization

- Major change -- decisions

Edit Guideline for Local Conditions

Guideline Localization

- Major change -- decisions

POSITION STATEMENT

Standards of Medical Care in Diabetes–2006

AMERICAN DIABETES ASSOCIATION

Diabetes is a chronic illness that requires continuing medical care and

Edit Guideline for Local Conditions

Guideline Localization

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POSITION STATEMENT

Standards of Medical Care in Diabetes–2006

American Diabetes Association

Diabetes is a chronic illness that requires continuing medical care and

Treatment recommendations and goals

In individuals with overt CVD

- All patients should be treated with a statin to achieve an LDL reduction of 30–40%. (A)
- A lower LDL cholesterol goal of <70 mg/dl (1.8 mmol/l), using a high dose of a statin, is an option. (B)

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Notify MD: CVD present so consider lower LDL goal of 70 (instance of Notify...

Label: Notify MD: CVD present so consider lower LDL goal of 70

Priority:

Subject:

Addressee: Primary care physician

Condition: Known CVD, but goal LDL not < 70

Communication Mode: Provider inbox communication protocol

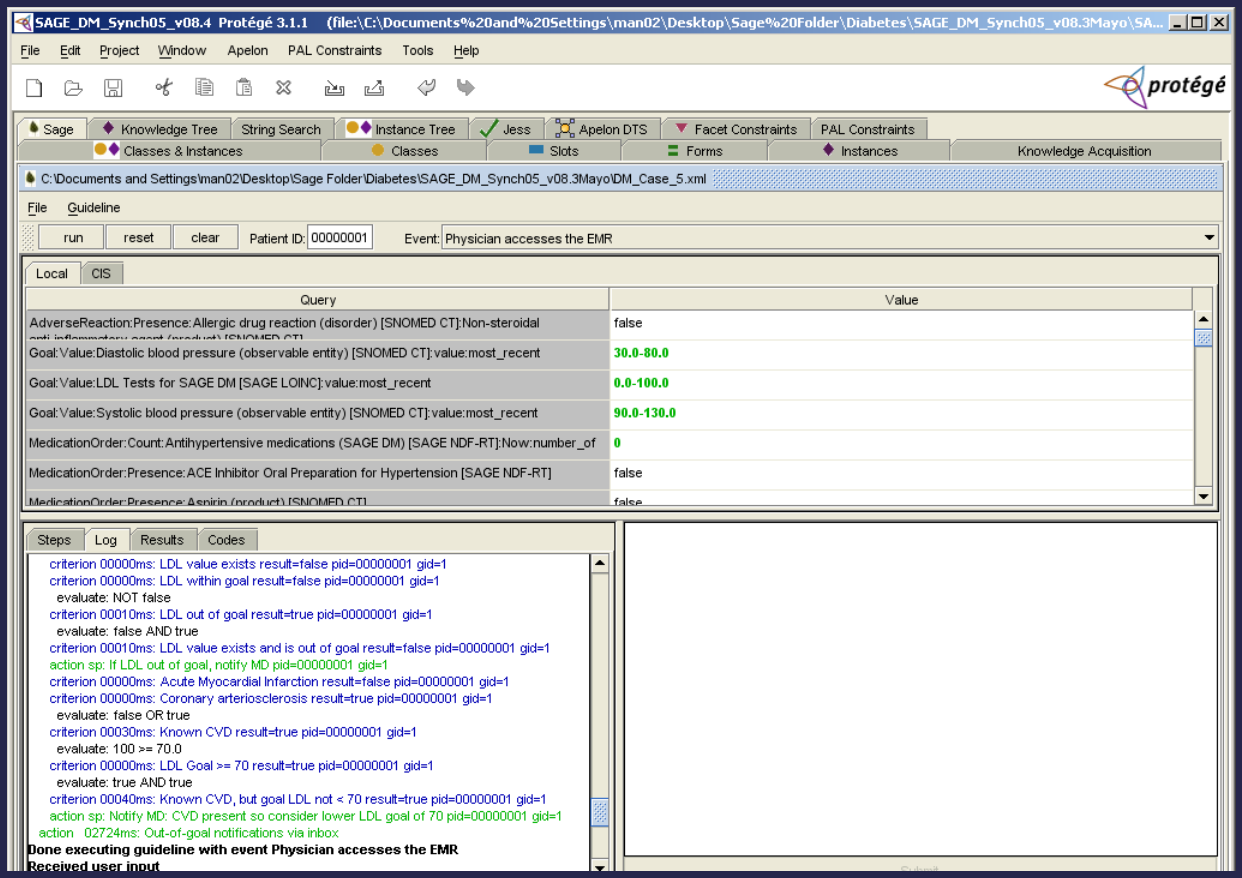
Parameterized String: Consider lower LDL goal of 70

SAGE

Edit Guideline for Local Conditions

Guideline Localization

Validate using SAGE Tab



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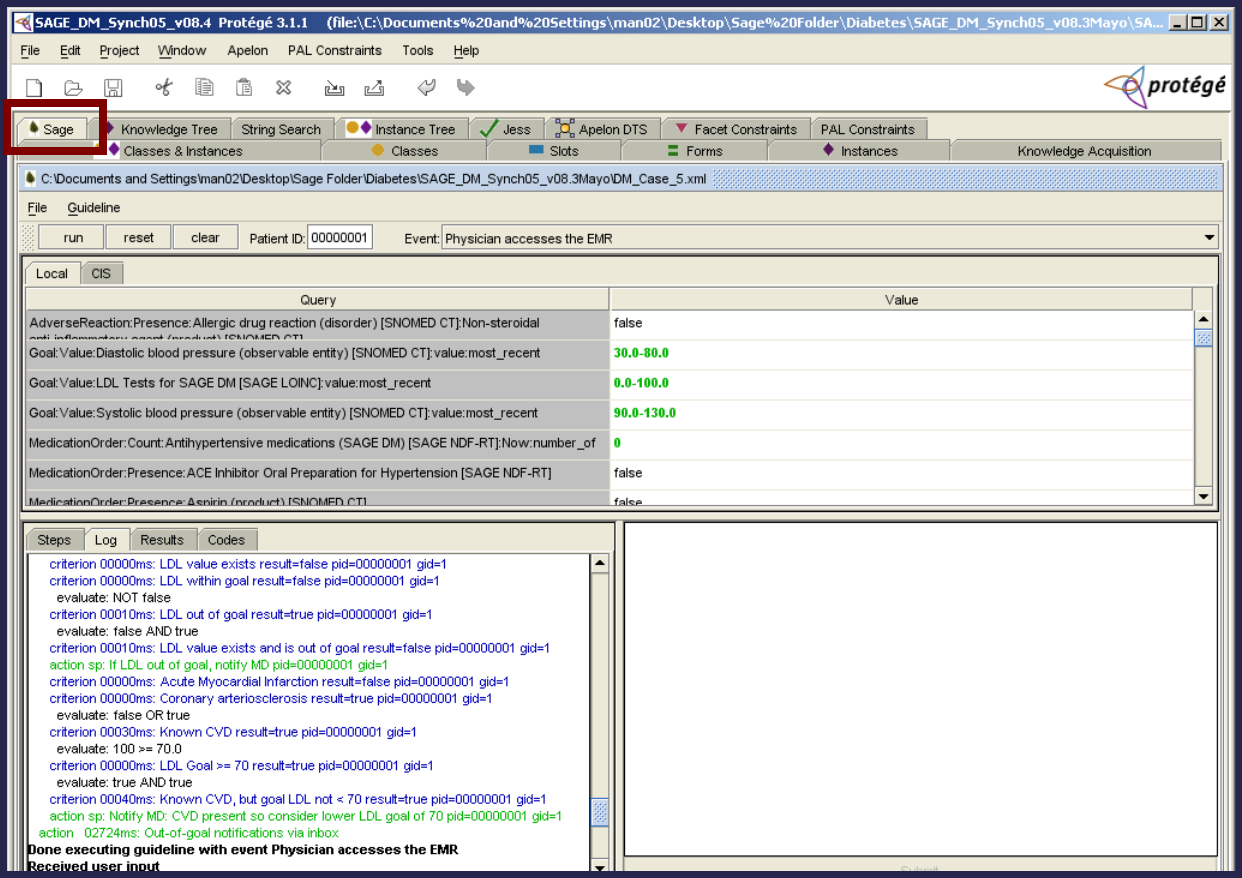
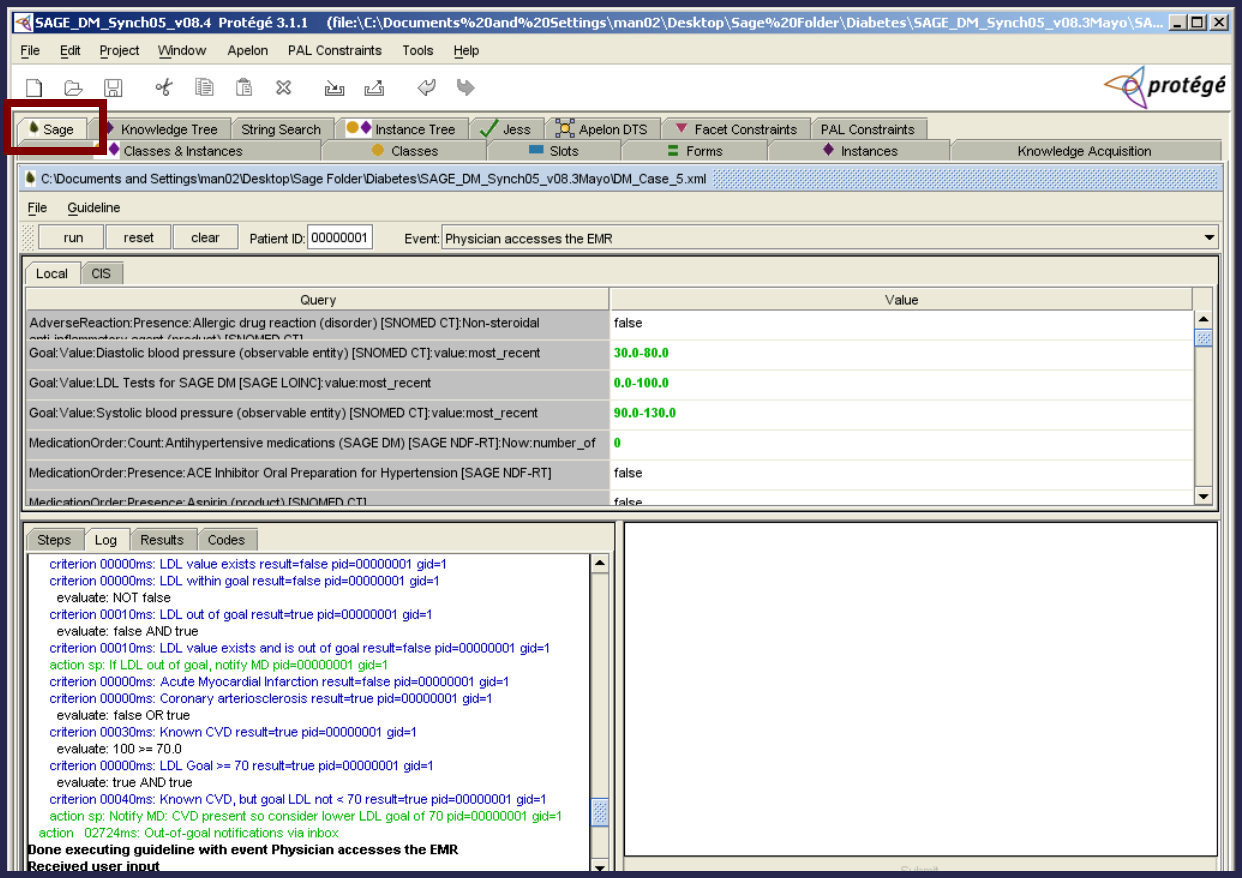


Edit Guideline for Local Conditions

Guideline Localization

Validate using SAGE Tab

Log Tab



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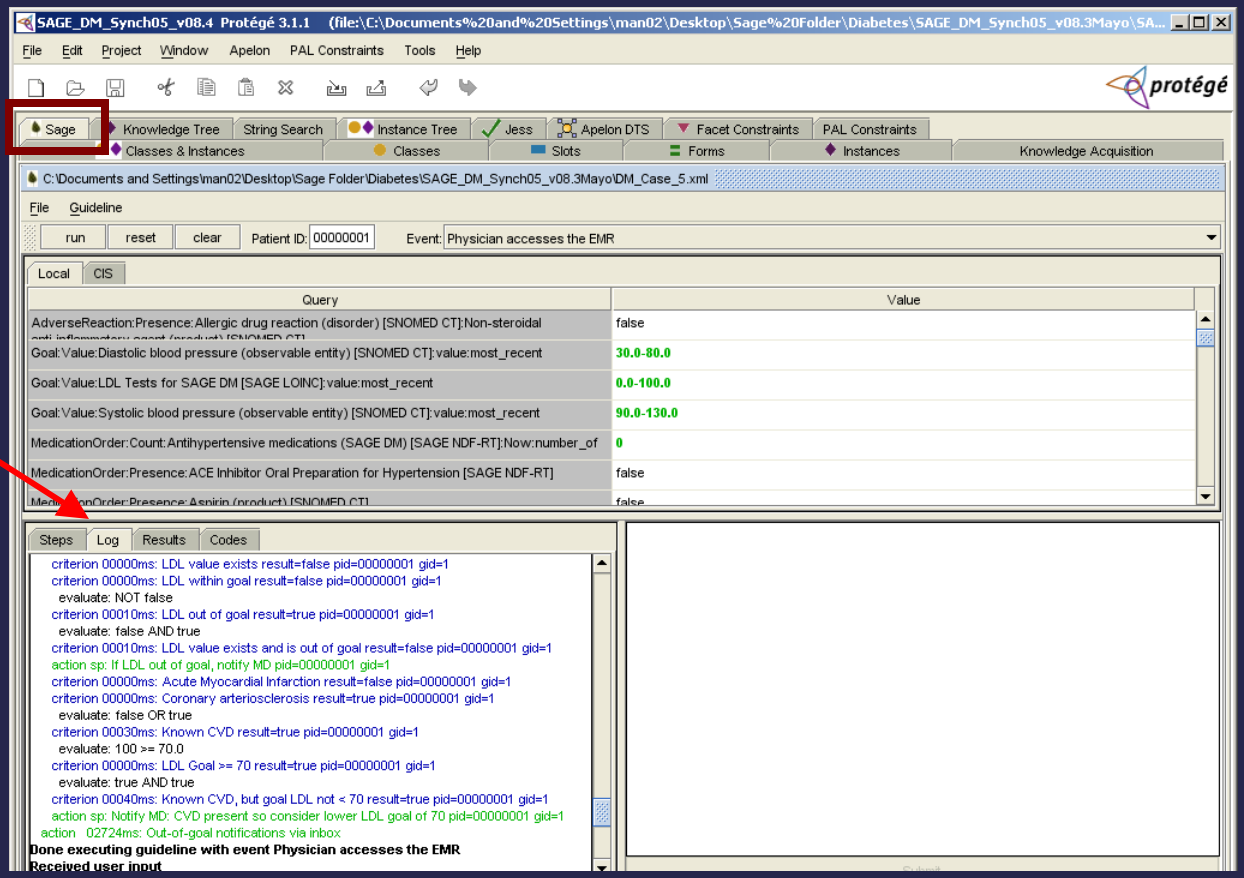

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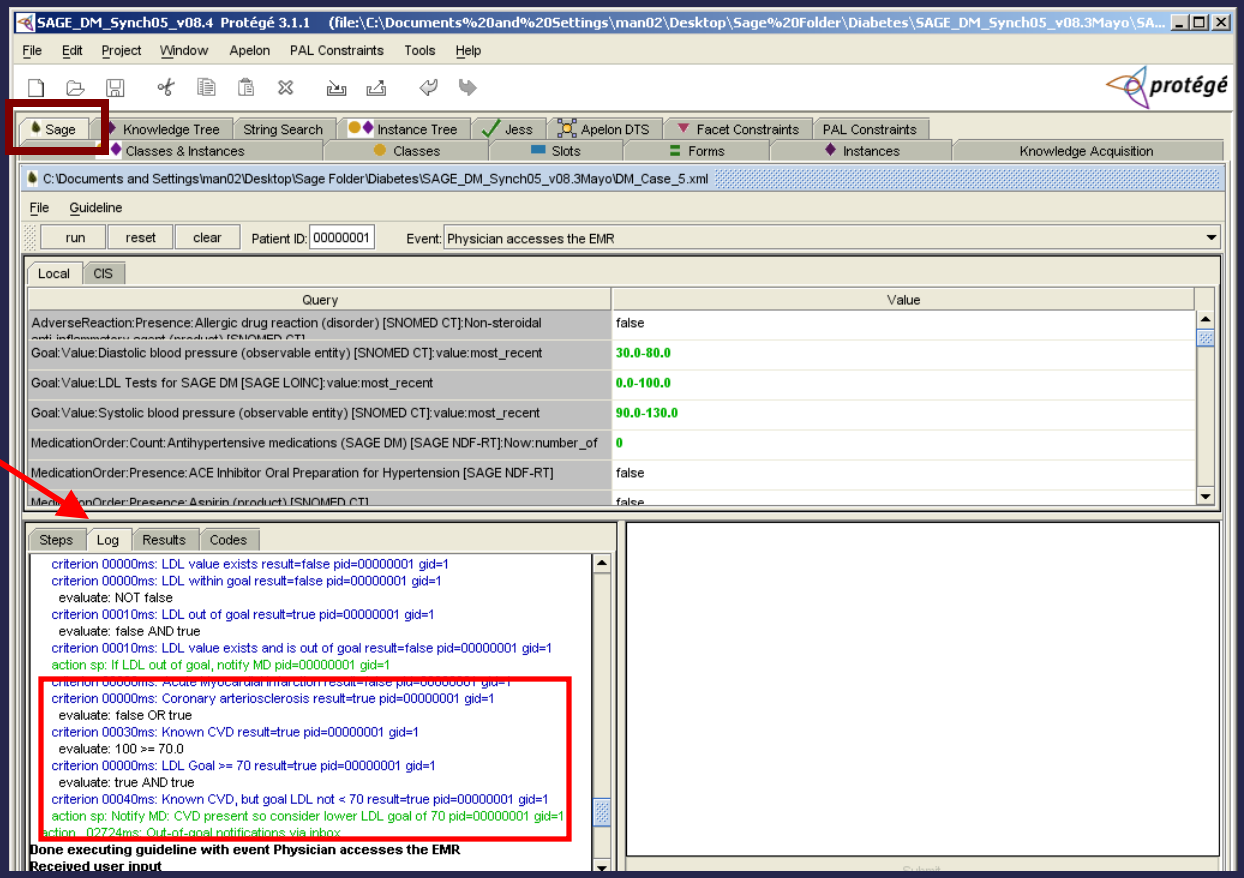

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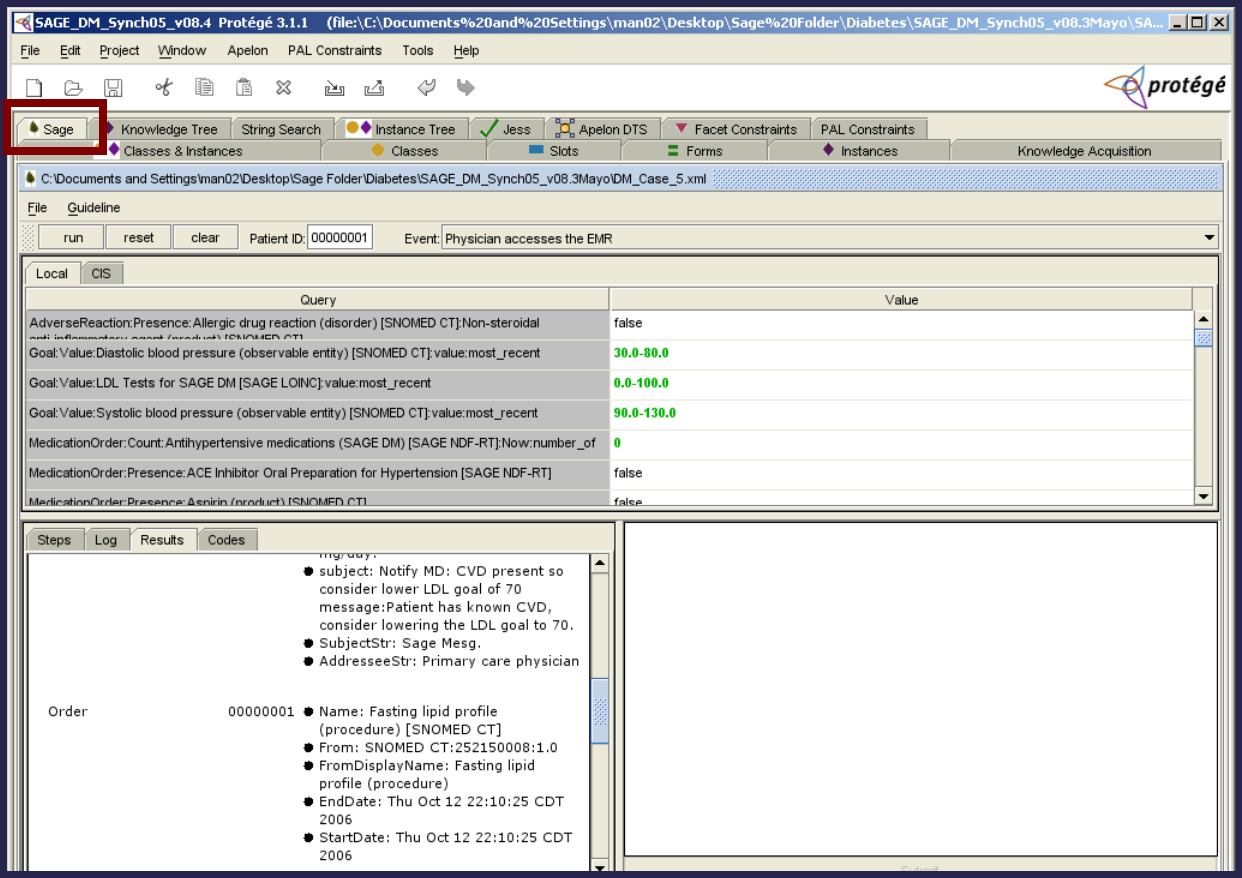
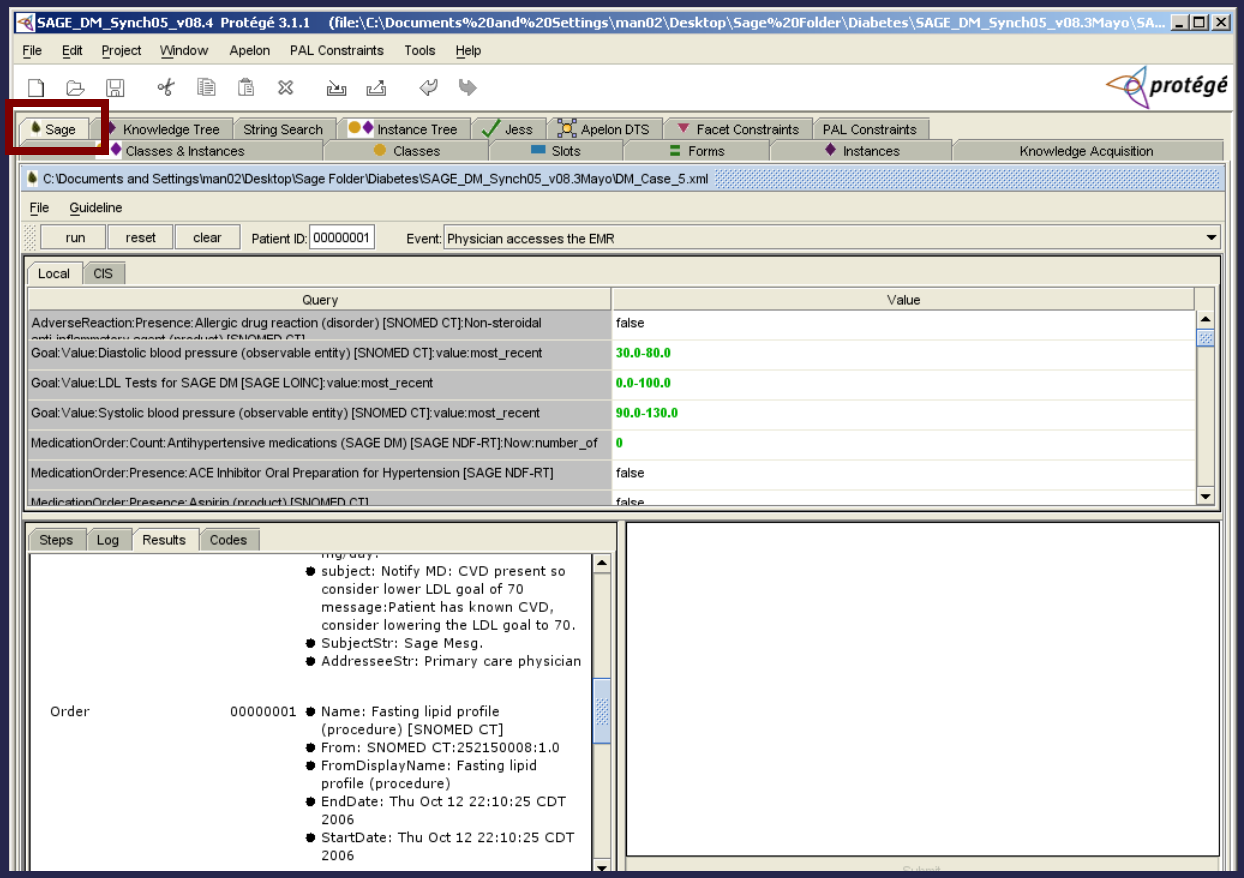


Edit Guideline for Local Conditions

Guideline Localization

Validate using SAGE Tab

Result Tab



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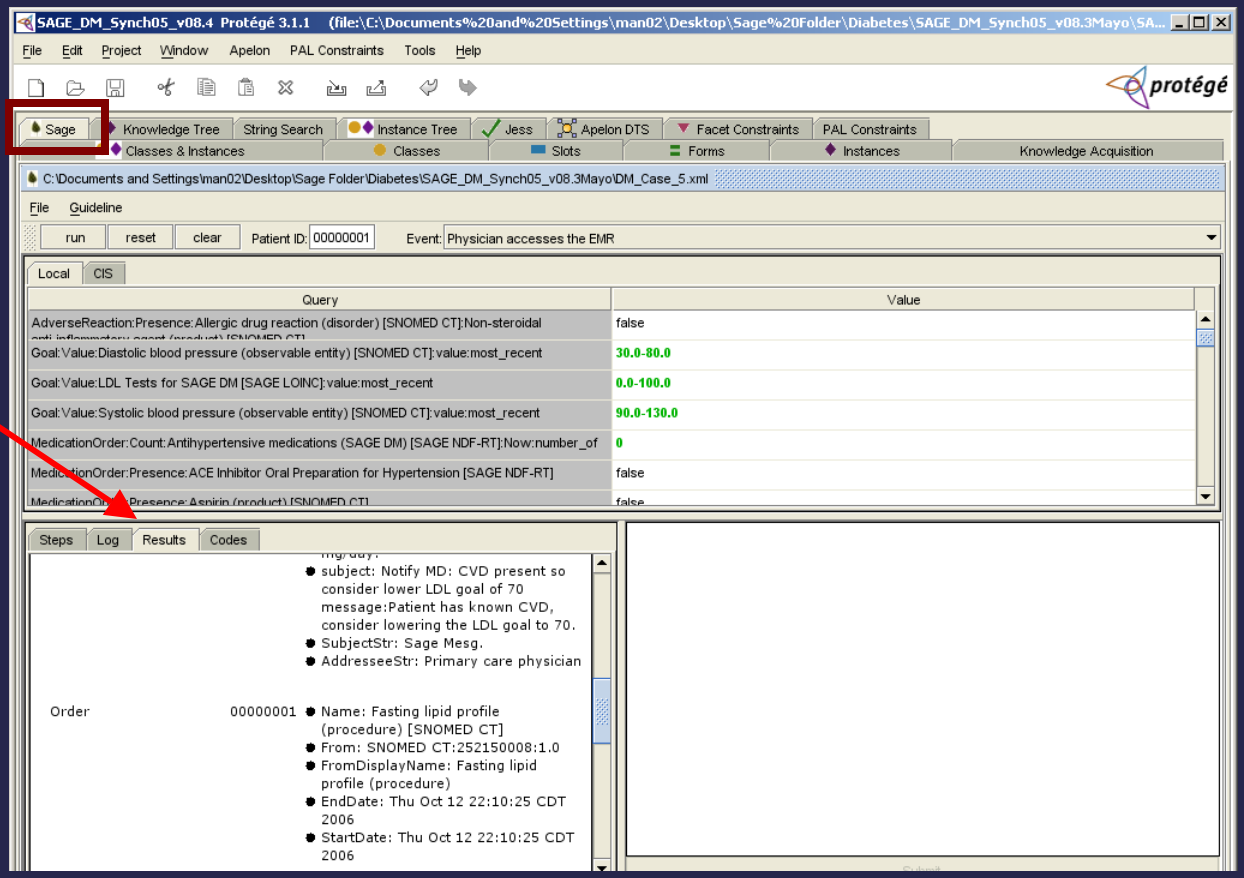
Guideline Localization

Validate using SAGE Tab

Result Tab



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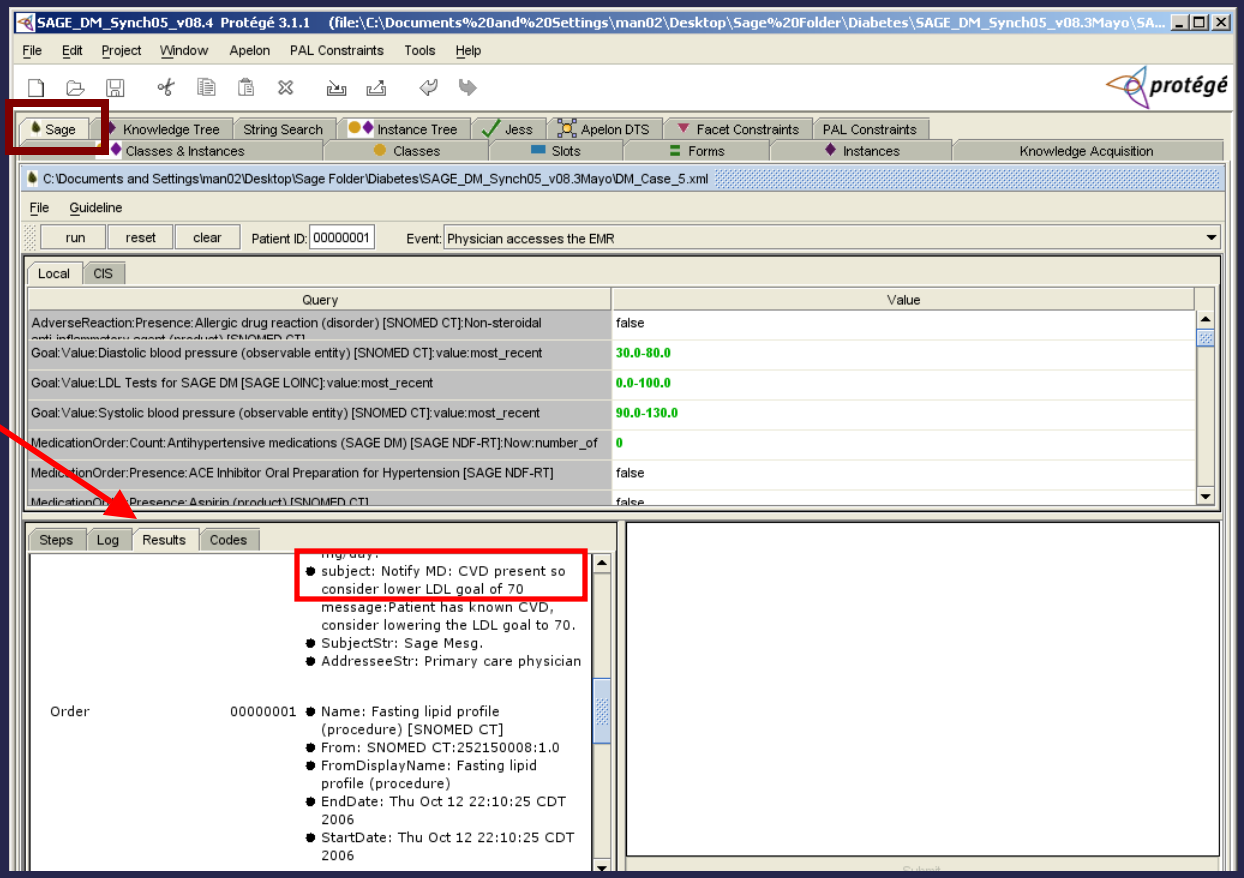
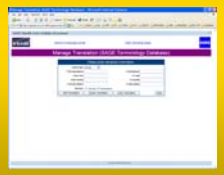


Map Standard to Local Terminologies



Mapping Terminologies

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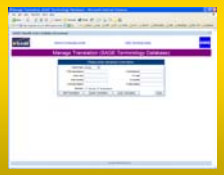

Mapping Terminologies

Standards-based coded content in SAGE Guideline

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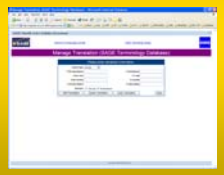

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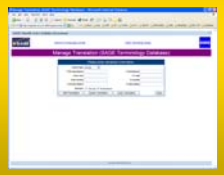

Mapping Terminologies

Standards-based coded content in SAGE Guideline → Must be Mapped To

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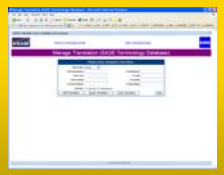

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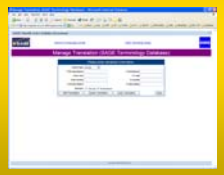

Mapping Terminologies

Standards-based coded content in SAGE Guideline → Must be Mapped To → Codes and terminologies used in host CIS

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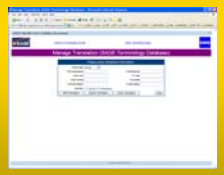


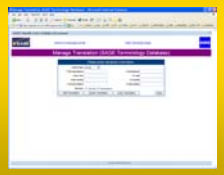
Mapping Terminologies

Standards-based coded content in SAGE Guideline → Must be Mapped To → Codes and terminologies used in host CIS

Diabetes Mellitus:

SNOMED-CT 73211009

Map Standard to Local Terminologies



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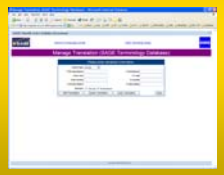

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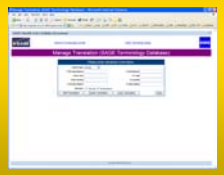
In the local CIS:

Problem Master Table

Diabetes Mellitus Sequence # 2566

SAGE

Map Standard to Local Terminologies



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SNOMED-CT 73211009

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SAGE

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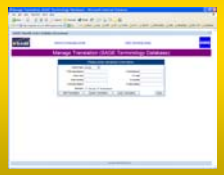

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SNOMED-CT 73211009

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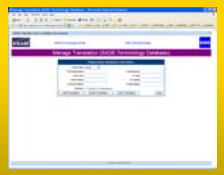

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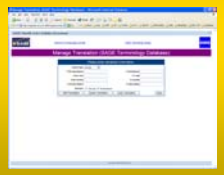
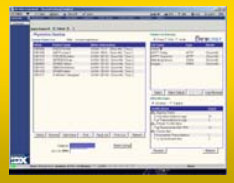


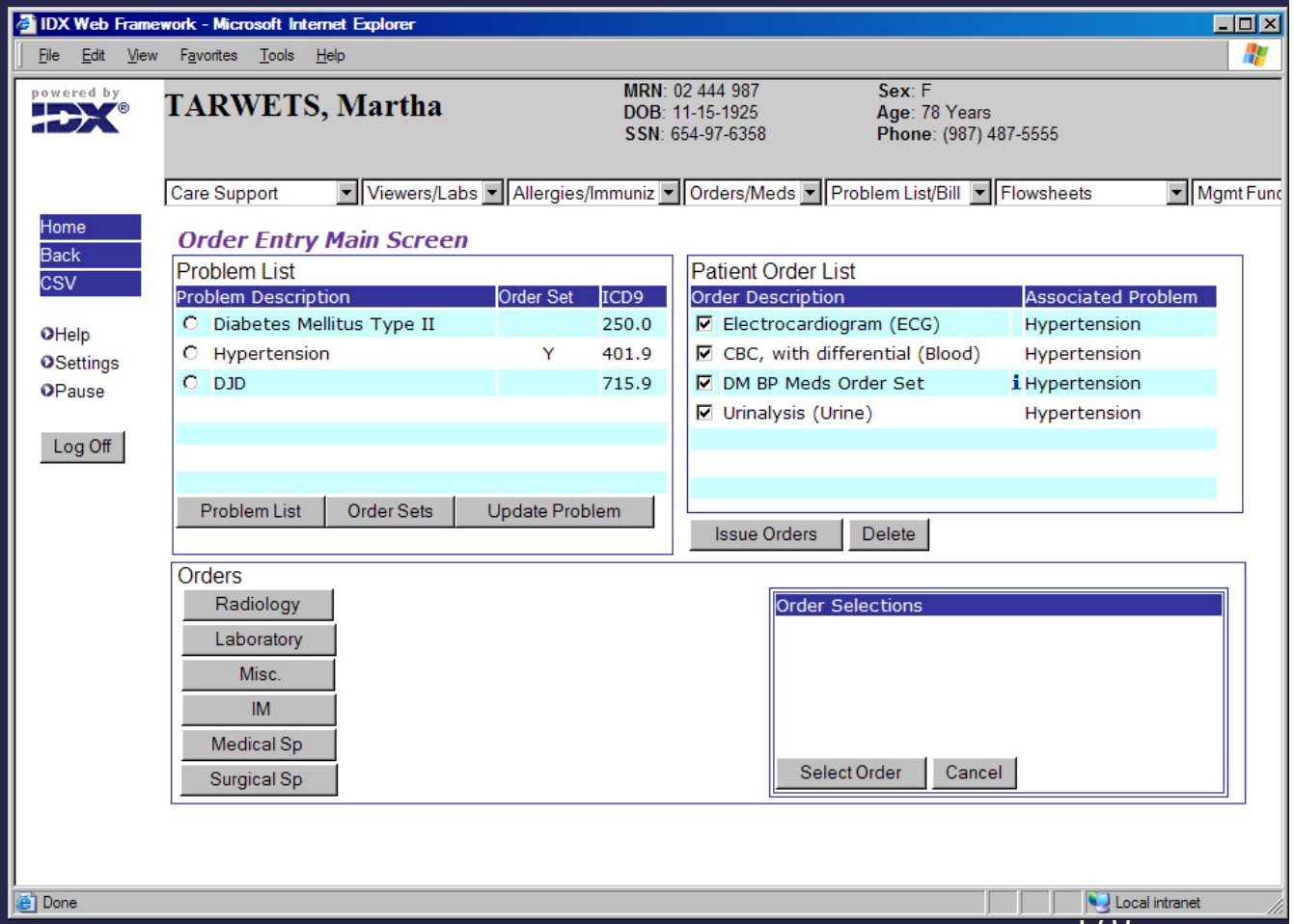
Mapping Terminologies

VMR Context	From concept	From concept label	Mayo label	Mayo lab code	Mayo master table
Problem	SNOMED: 73211009	Diabetes mellitus	DM		2202566
Problem	SNOMED: 46635009	Diabetes mellitus type 1	DM type 1		2202569
Problem	SNOMED: 44054006	Diabetes mellitus type 2	DM type 2		2202567
Observation	LOINC: 4548-4	Hemoglobin A1C	Hemoglobin A1C, B (Roch)	82080-ROCLIS	6105267
			Hemoglobin A1C, B (Kasson)	82990-ROCLIS	6105673
Order	LOINC: 4548-4	Hemoglobin A1C	Hemoglobin A1C,B	82080-ROCLIS	2001006

Activate Guideline



User Interface



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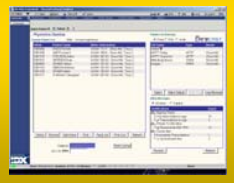
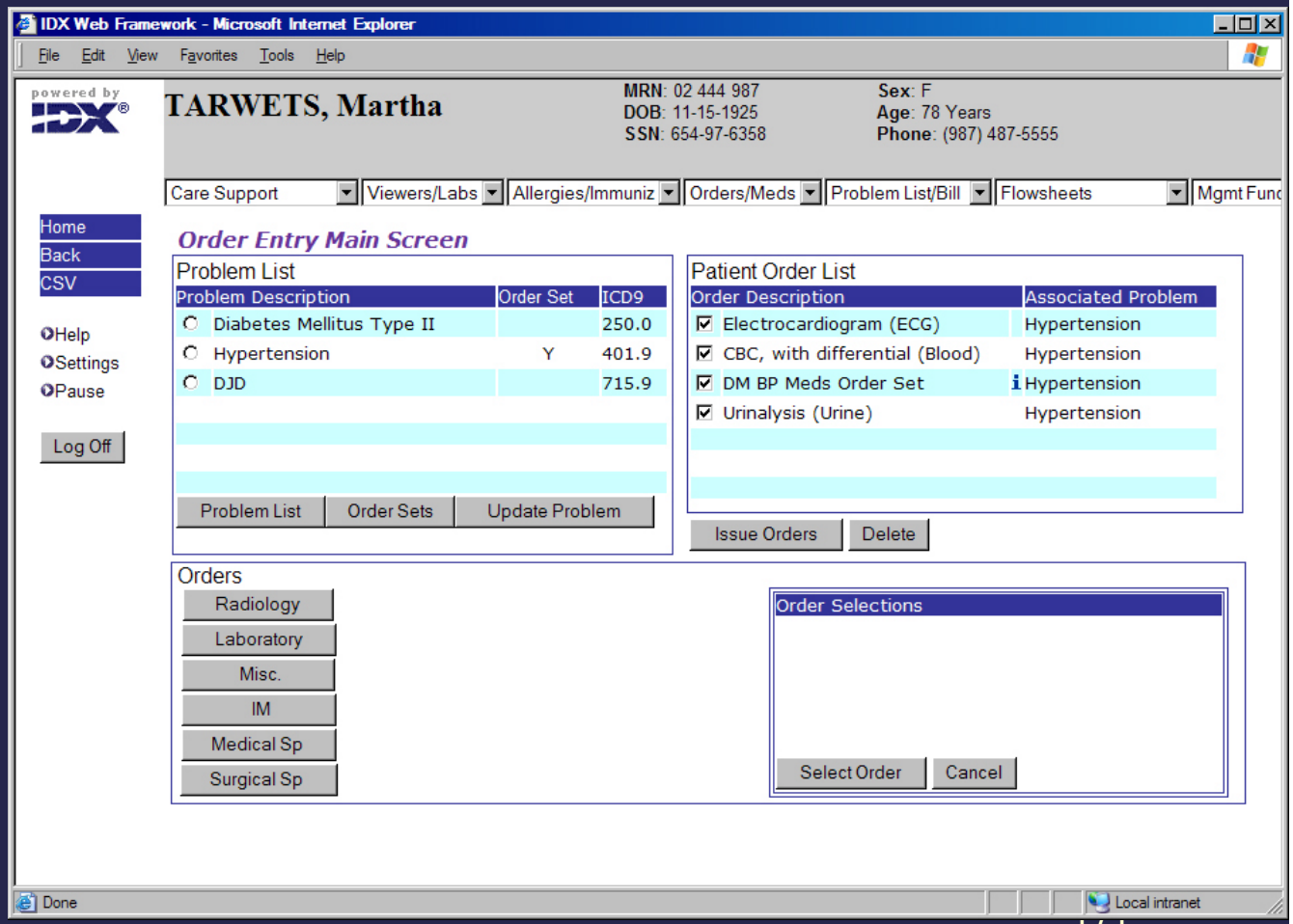


User Interface

Present guideline recommendations as orders ready for the clinician to issue.



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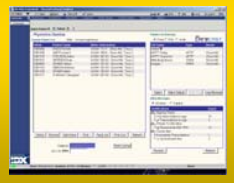

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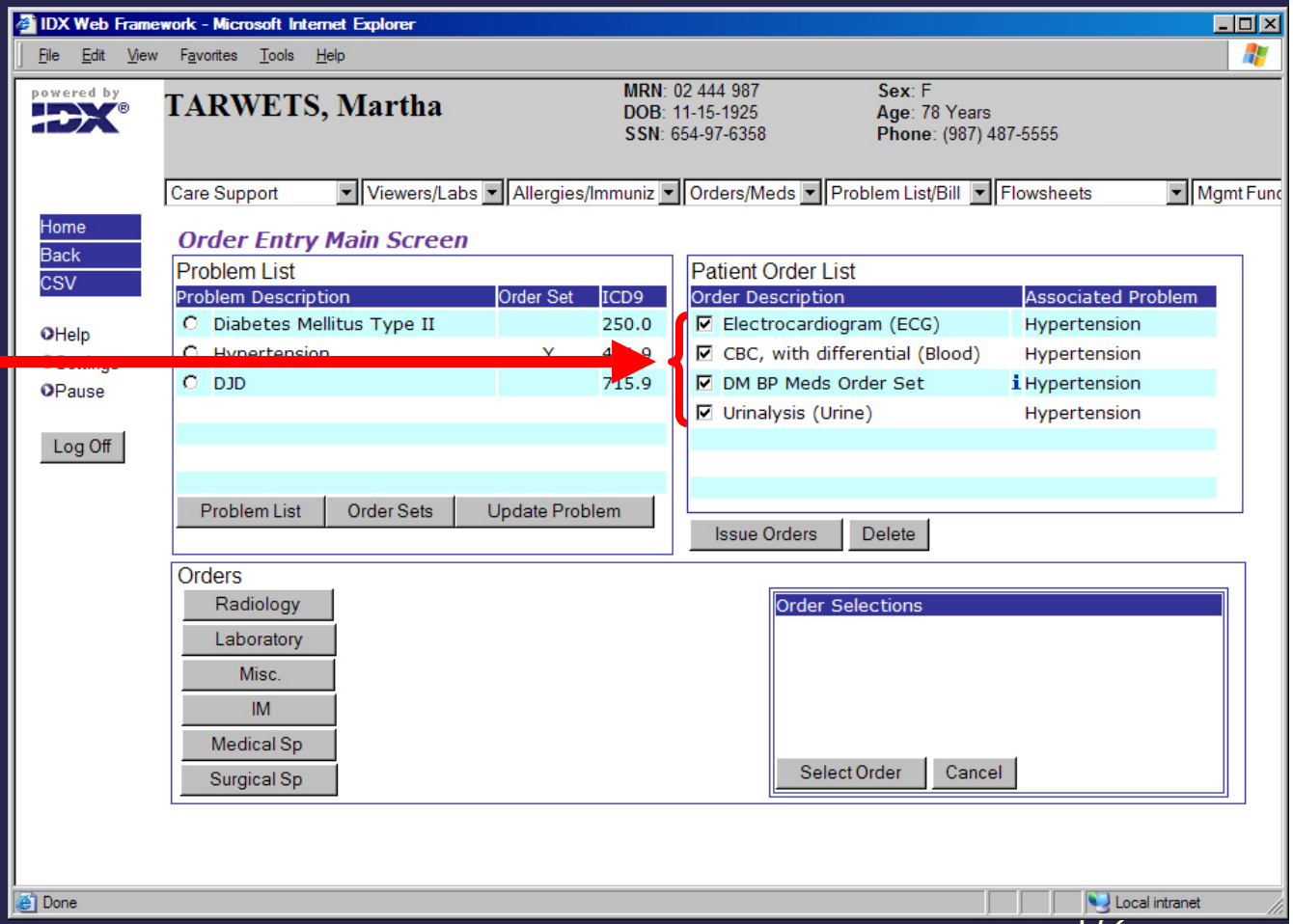

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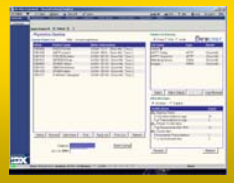

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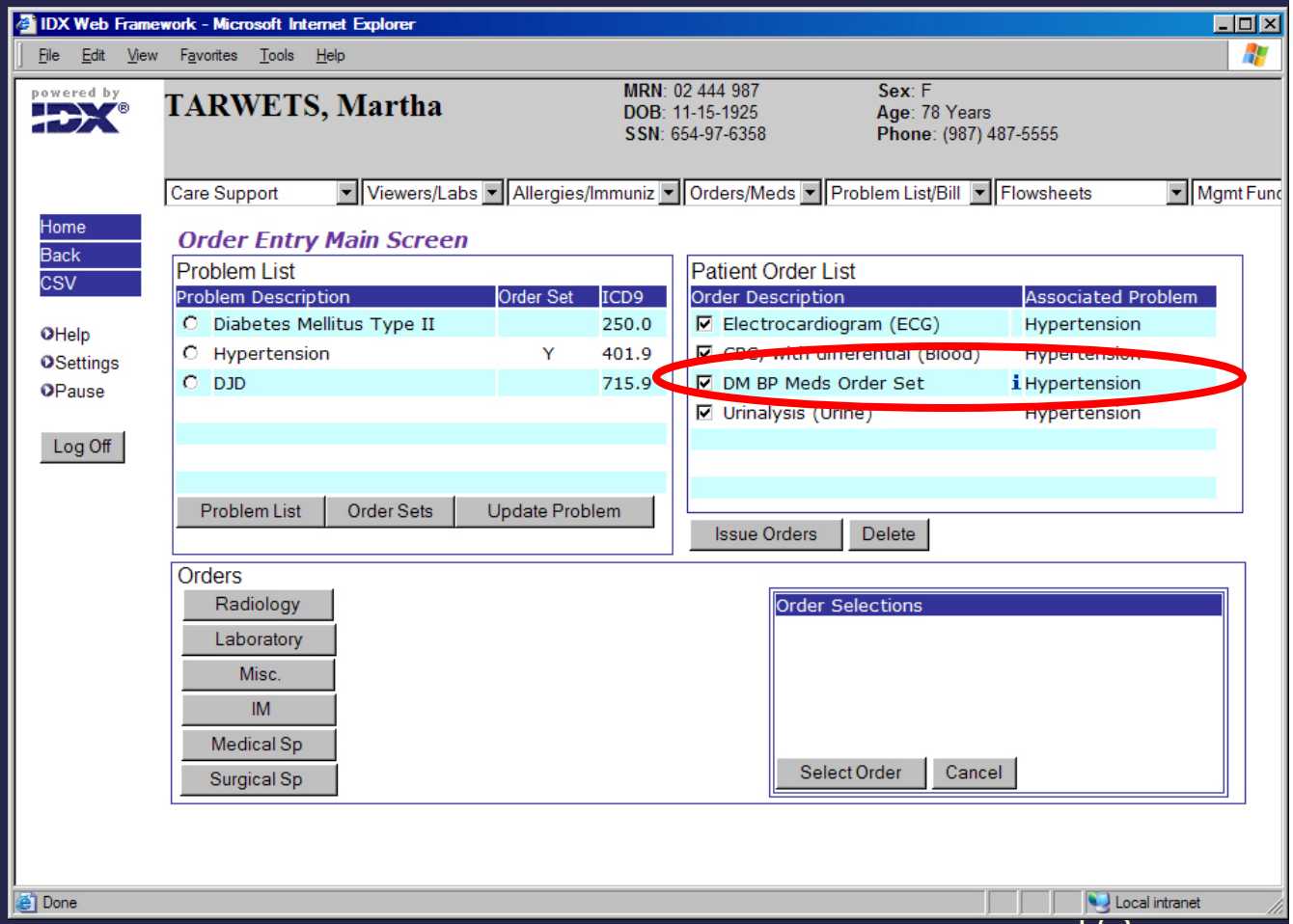

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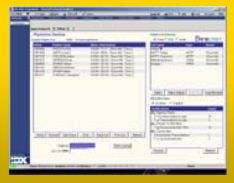
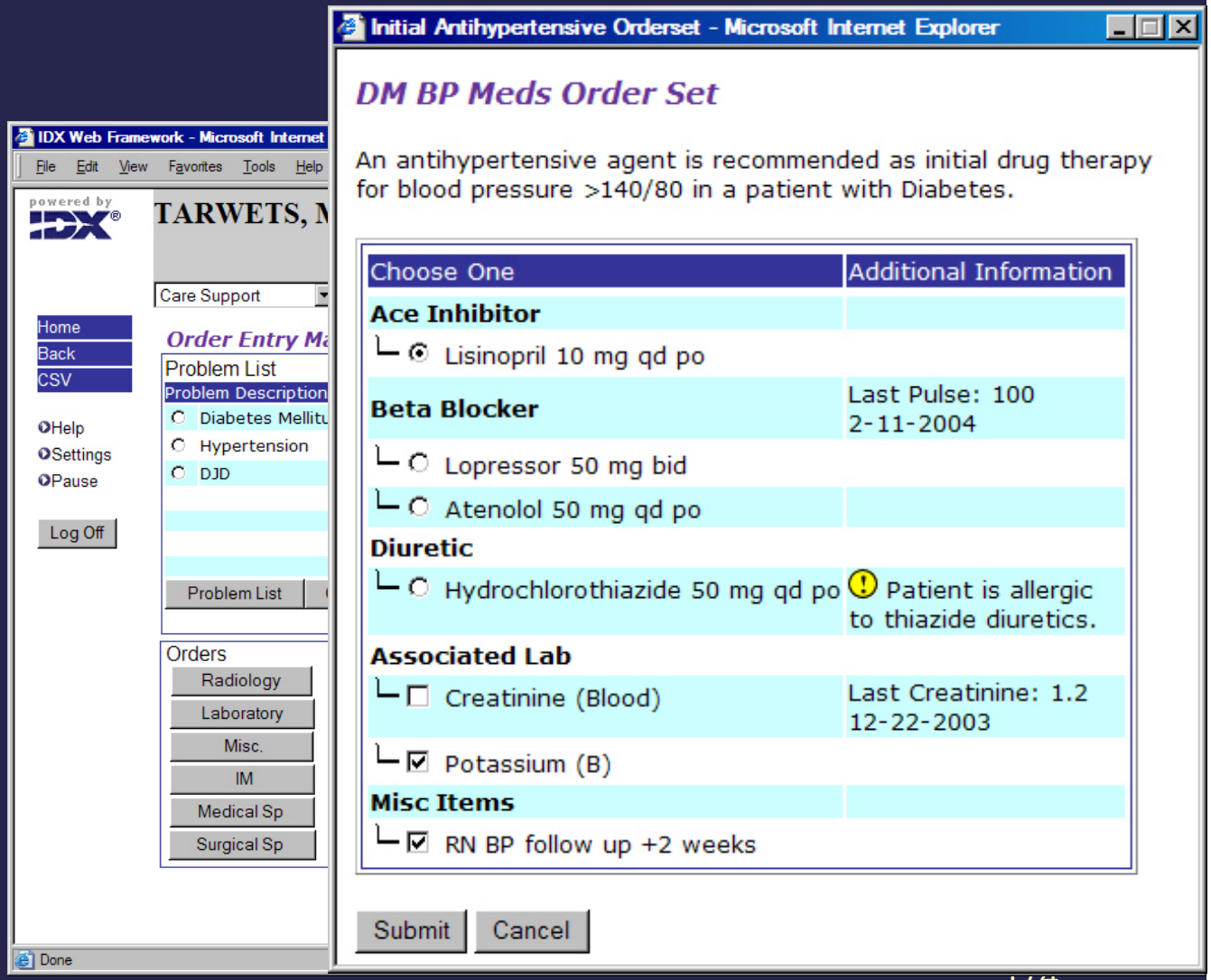
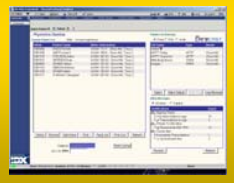


User Interface

Present guideline recommendations as orders ready for the clinician to issue.



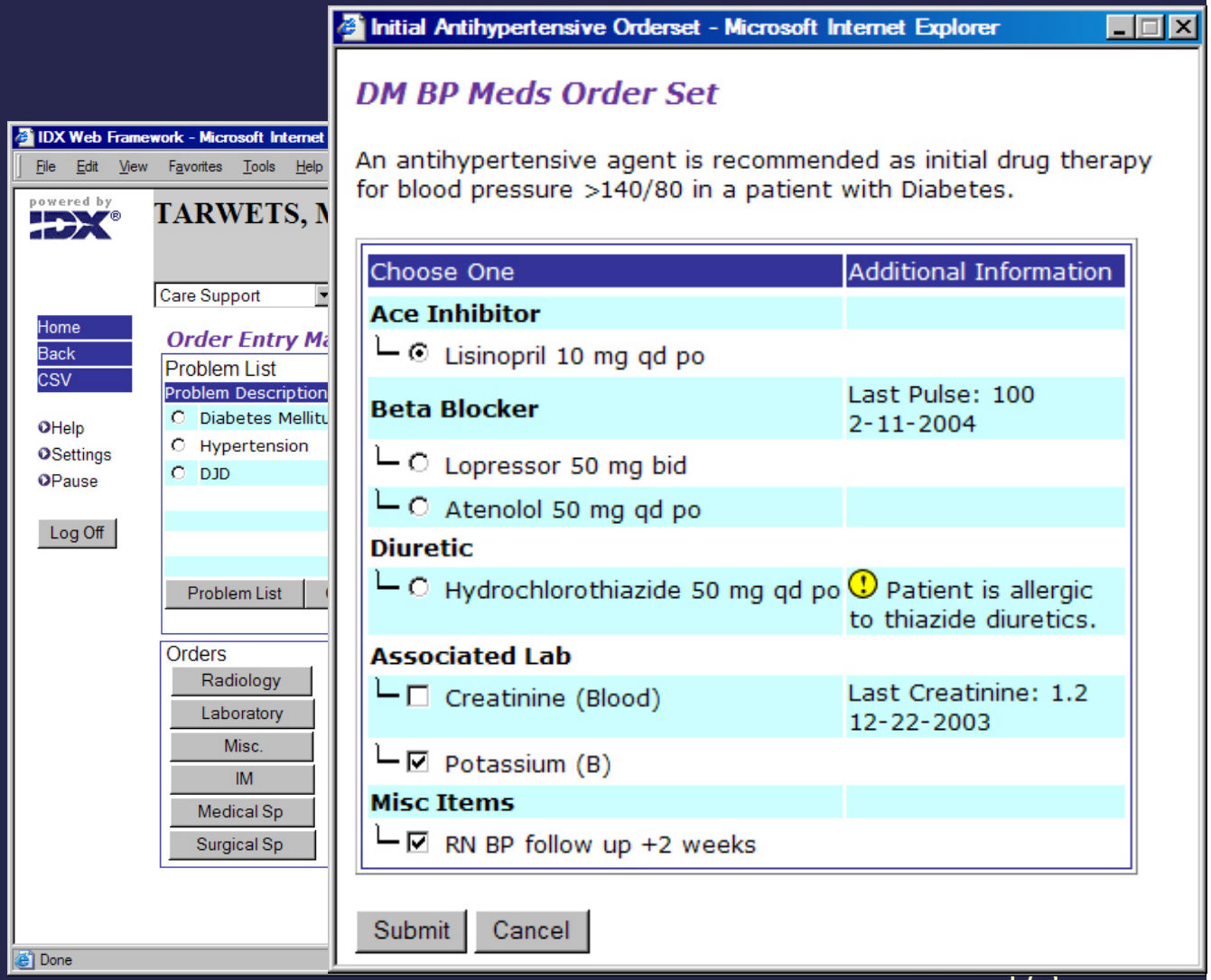
Activate Guideline



User Interface

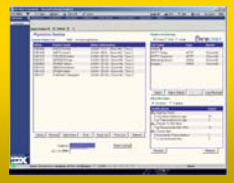
Present guideline recommendations as orders ready for the clinician to issue.

Ordersets with SAGE driven annotations.



SAGE

Activate Guideline



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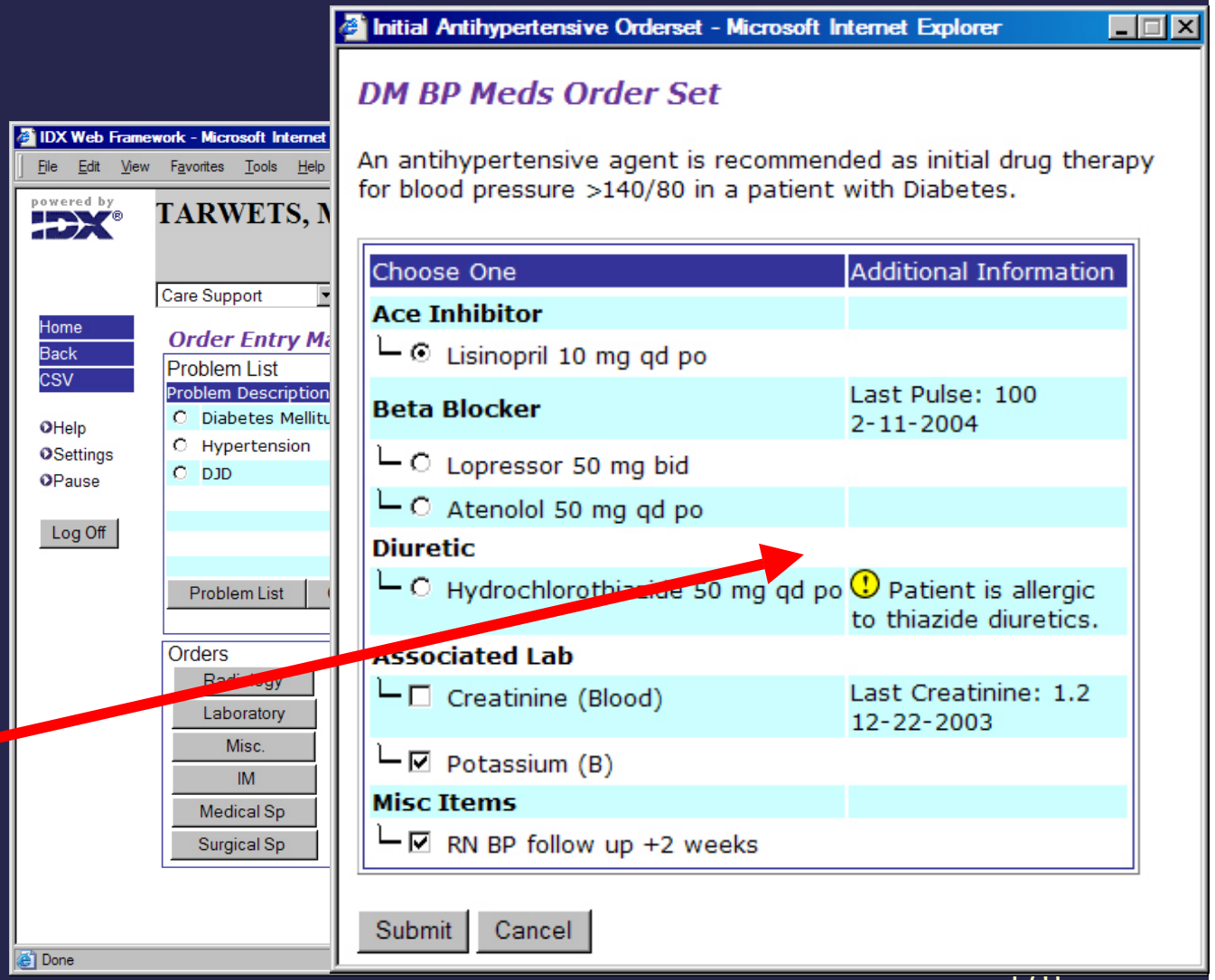
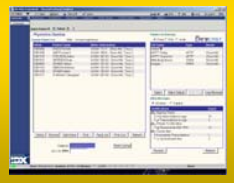


SAGE

User Interface

Activate Guideline



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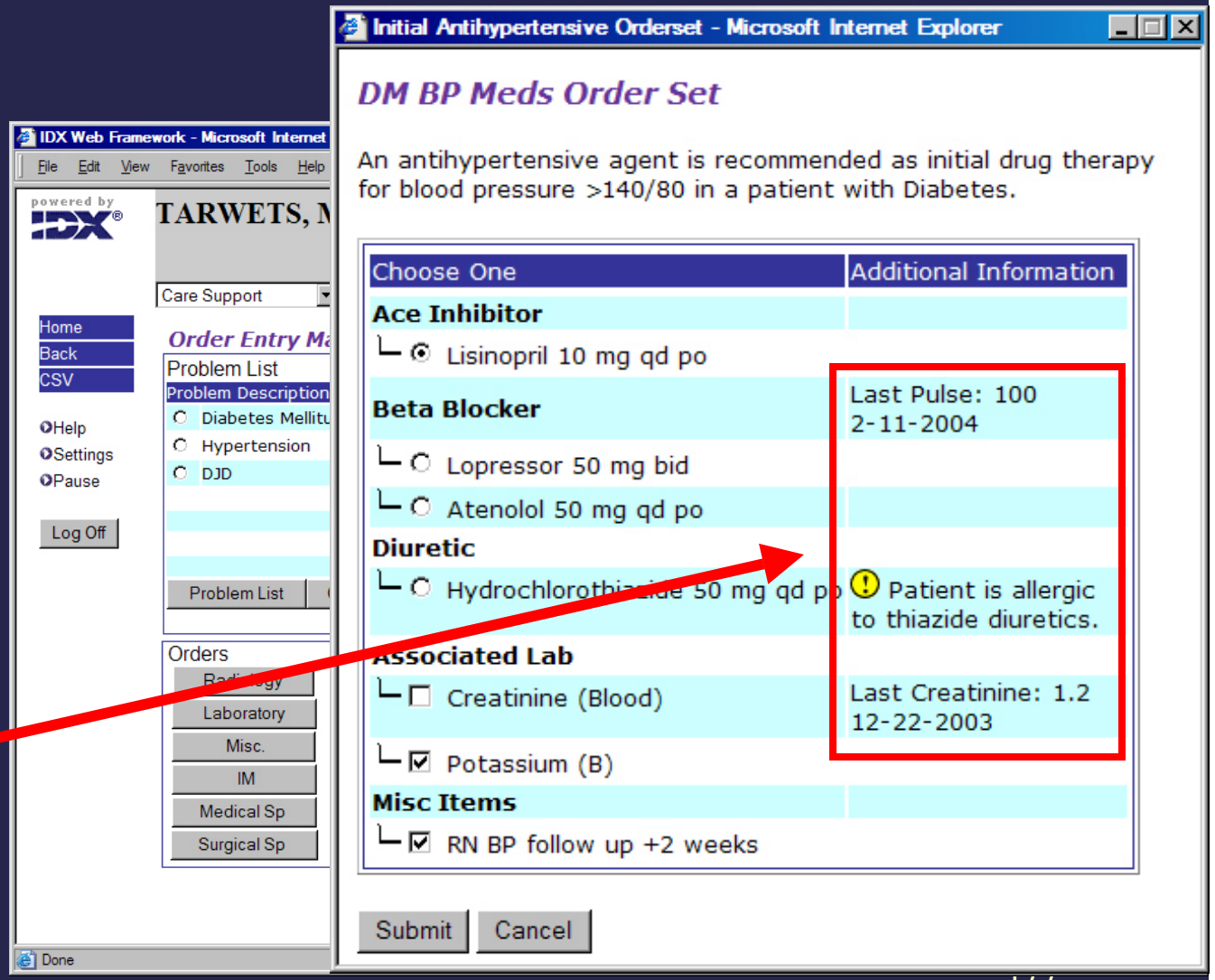
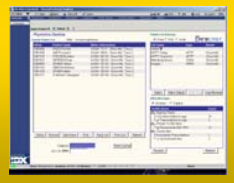


SAGE

Activate Guideline



Guideline Flow Sheets

Summary flow sheet of guideline specific information.

IDX Web Framework - Microsoft Internet Explorer

File Edit View Favorites Tools Help

powered by IDX

TARWETS, Martha

MRN: 02 444 987 **Sex**: F
DOB: 11-15-1925 **Age**: 78 Years
SSN: 654-97-6358 **Phone**: (987) 487-5555

Care Support | Viewers/Labs | Allergies/Immuniz | Orders/Meds | Problem List/Bill | Flowsheets | Mgmt Func

Home
Back
CSV

Help
Settings
Pause

Log Off

Care Support

Document | Add Column | Audit | Edit

ALL | DM | HTNX

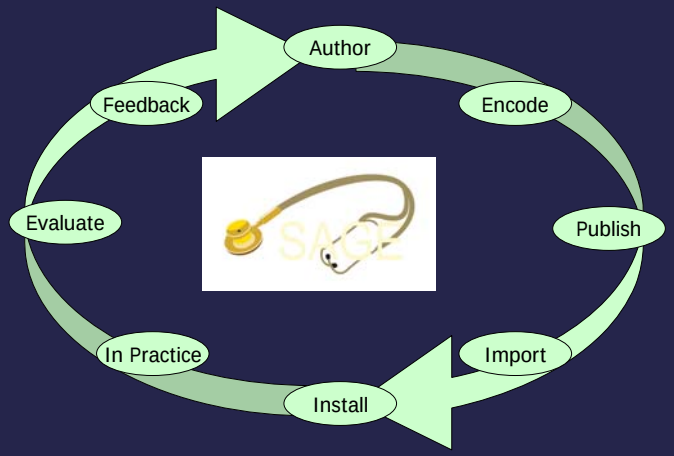
Item	Info	Status	2-12-2004	12-22-2003	11-25-2002	09-25-2001	07-24-2000
Assessments							
Imm Screening				Done	Done	Done	Done
Foot Exam	i	Due			Normal	Normal	
Eye Exam	i			Normal		Normal	Normal
Tobacco Use	i		No	No	No	No	No
Blood Pressure	i		146/90	142/89	125/70	120/60	140/90
Tests							
Hb,A1C	i			6.4	6.6	6.6	6.4
Creatinine				1.2	1.4	1.3	1.6
Cholesterol (S)				165	170	168	170
Triglycerides (S)				104	107	105	110
HDL Chol (S)				51	49	52	45
LDL, Calculated	i			93	99	101	90
Albumin/Creat	i			18	16	18	17
Medications							
ASA				81 mg	81 mg	81 mg	81 mg
Glucotrol				10 mg	10 mg	10 mg	10 mg
Actos				4 mg	4 mg	4 mg	4 mg
Immunizations							

Done Local intranet

SAGE

Summary of Accomplishments

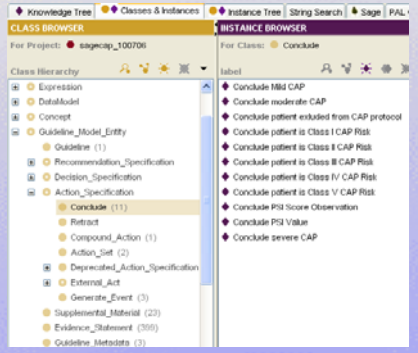
Robert Abarbanel, MD, Ph.D.
GE Healthcare, Seattle



SAGE Infrastructure - Accomplishments

Clinical Practice Guidelines

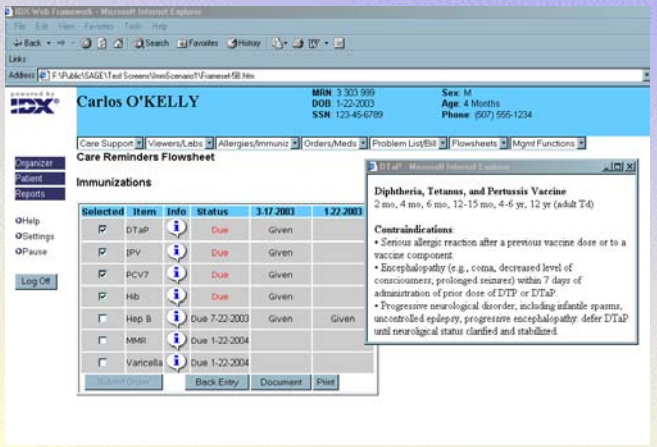
Controlled Resources



SAGE Guideline Model

Guideline Encoding

The SAGE Engine



Host Clinical Information System

Guideline Representation

- Support interoperability via use of standard information models and terminologies.
- Support comprehensive encoding of complex, longitudinal care practice guidelines.
- Support complex, computable models of medical decisions and recommended actions.
- Provide workflow-aware, event-aware, context-specific decision support.

Guideline Encoding

- Support multi-level (e.g., clinicians, experts) representation of guideline encoding.
- Provide integrated terminology services and guideline testing during encoding.
- Support local review and editing of guideline content.
- Allow reuse of encoded guideline components.

SAGE

Guideline Execution

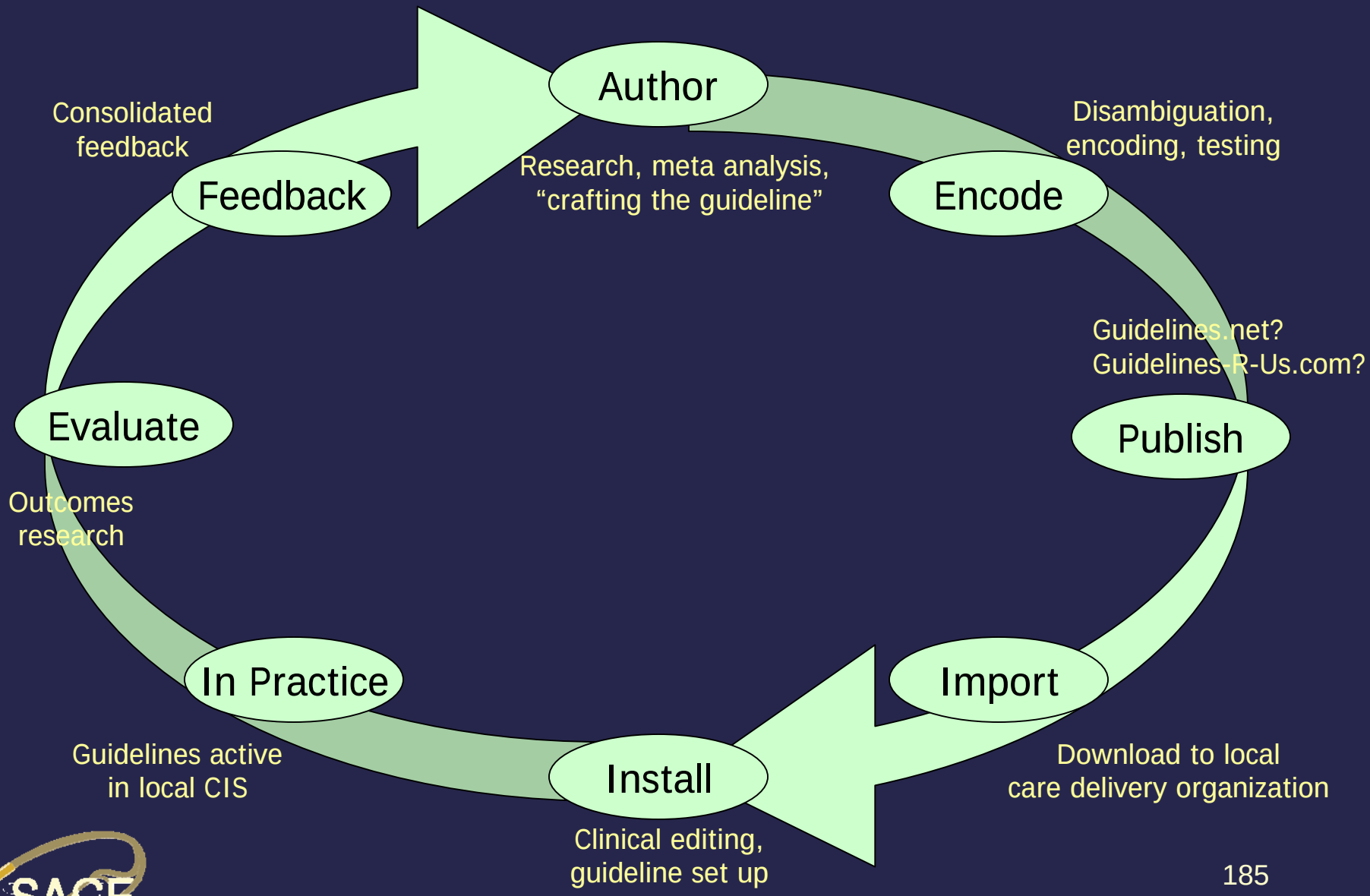
Interface to Host CIS

- Support event-based, time-based activation of guideline logic.
- Execute guideline logic and query patient-data in real time.
- Interoperate with local terminology services and external knowledge bases.
- Support surveillance-mode and population-based guideline execution.
- Employ standard information models and web services for data queries.
- Detect appropriate CIS events.
- Transmit guideline-based actions to the host CIS.

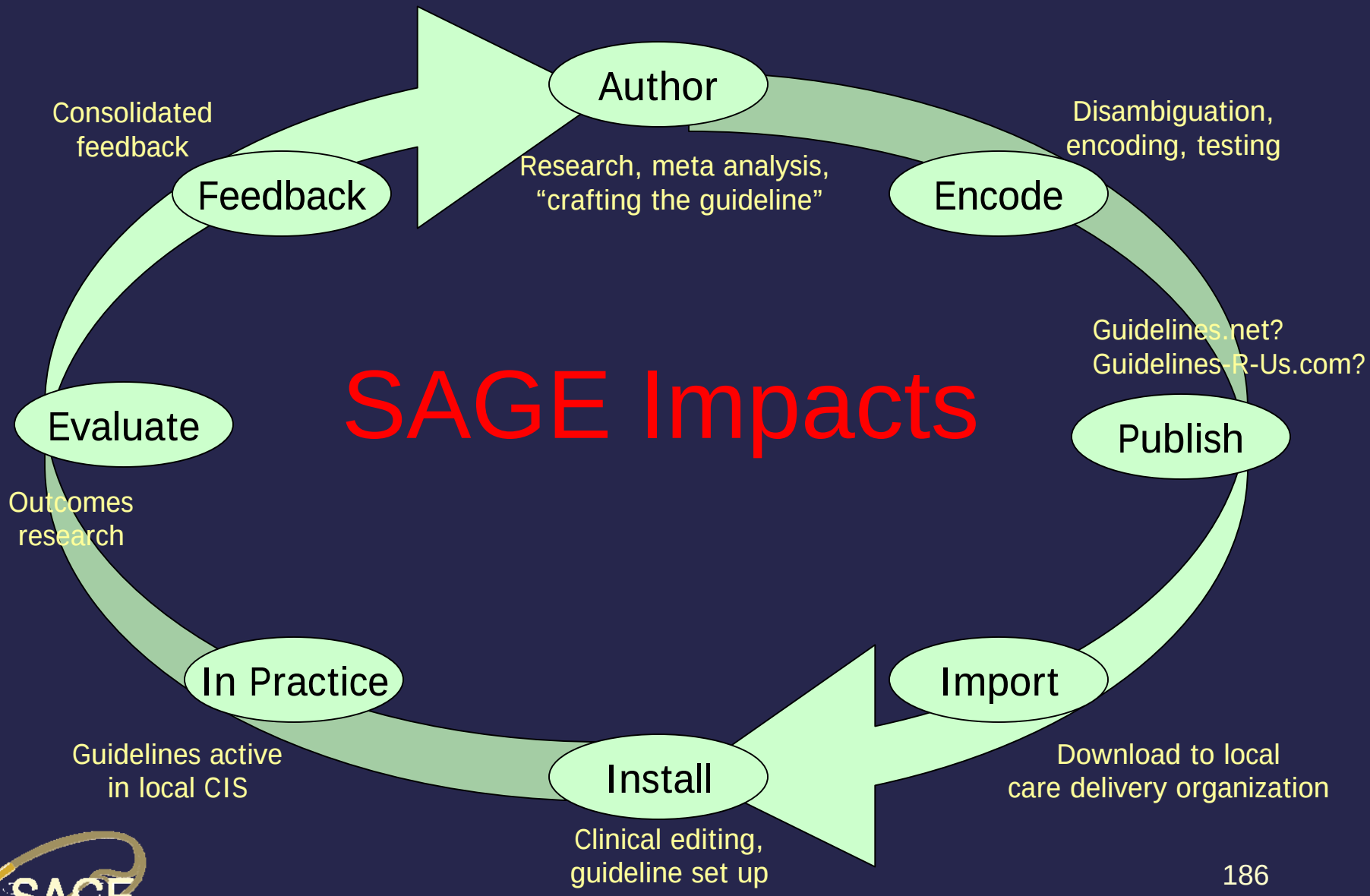
CIS Effectors

- Surface guideline recommendations via native CIS functionality.
- Integrate guideline recommendations with clinical care workflow.
- Store guideline recommendations, enrollment, and goals as part of the patient record.
- Support synchronous guideline-driven alerts and interaction.

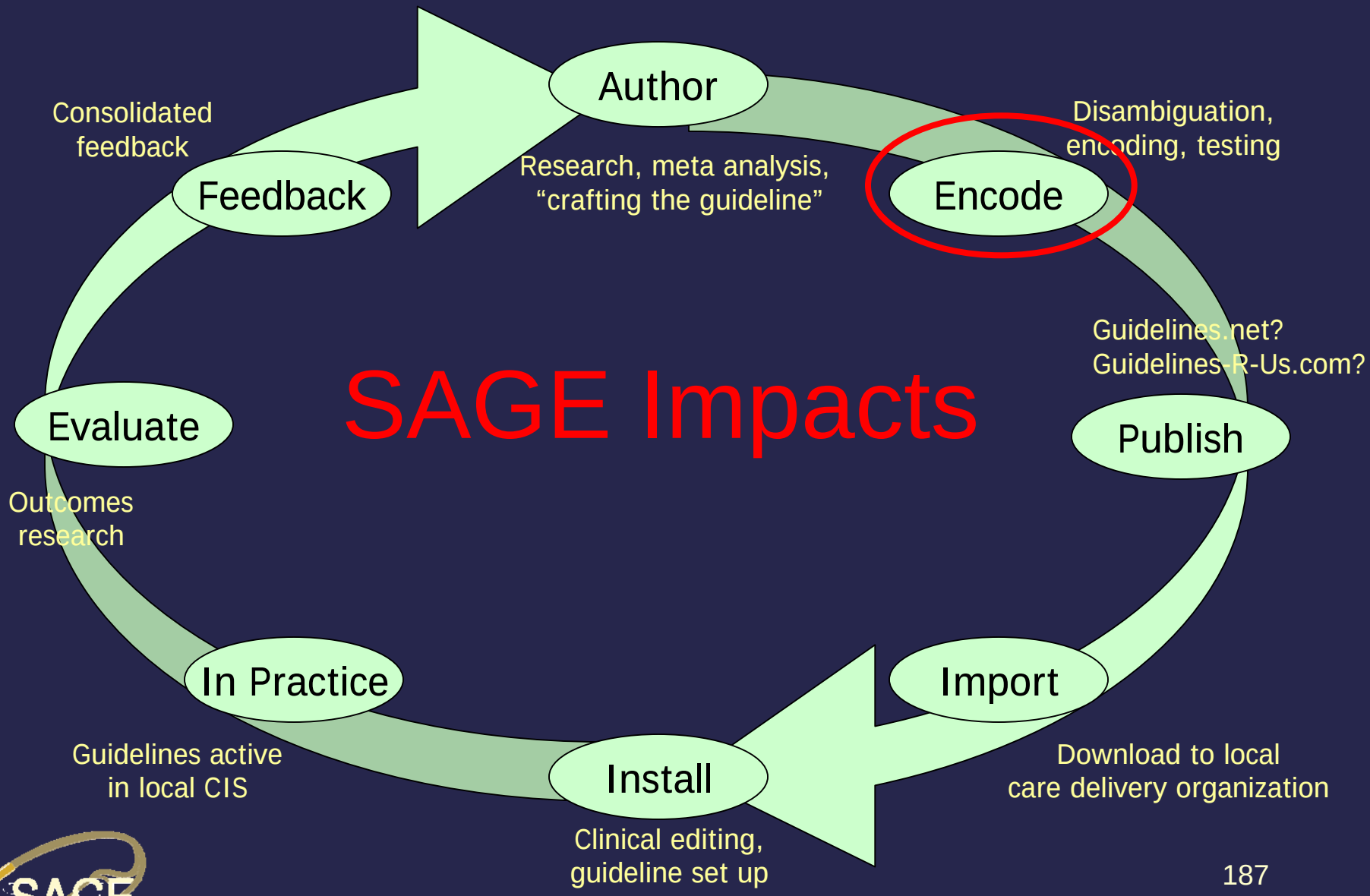
Guideline Lifecycle Vision



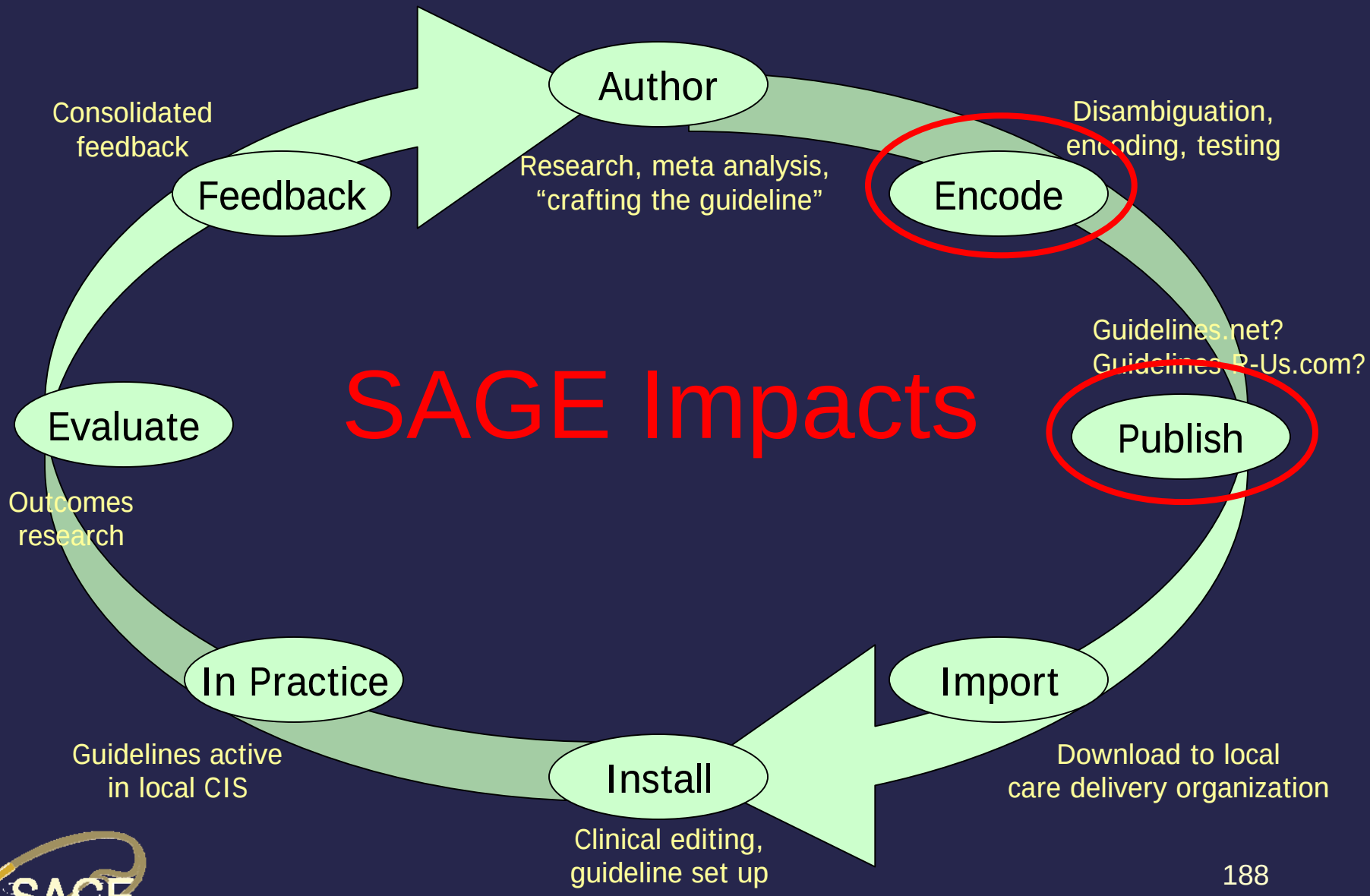
Guideline Lifecycle Vision



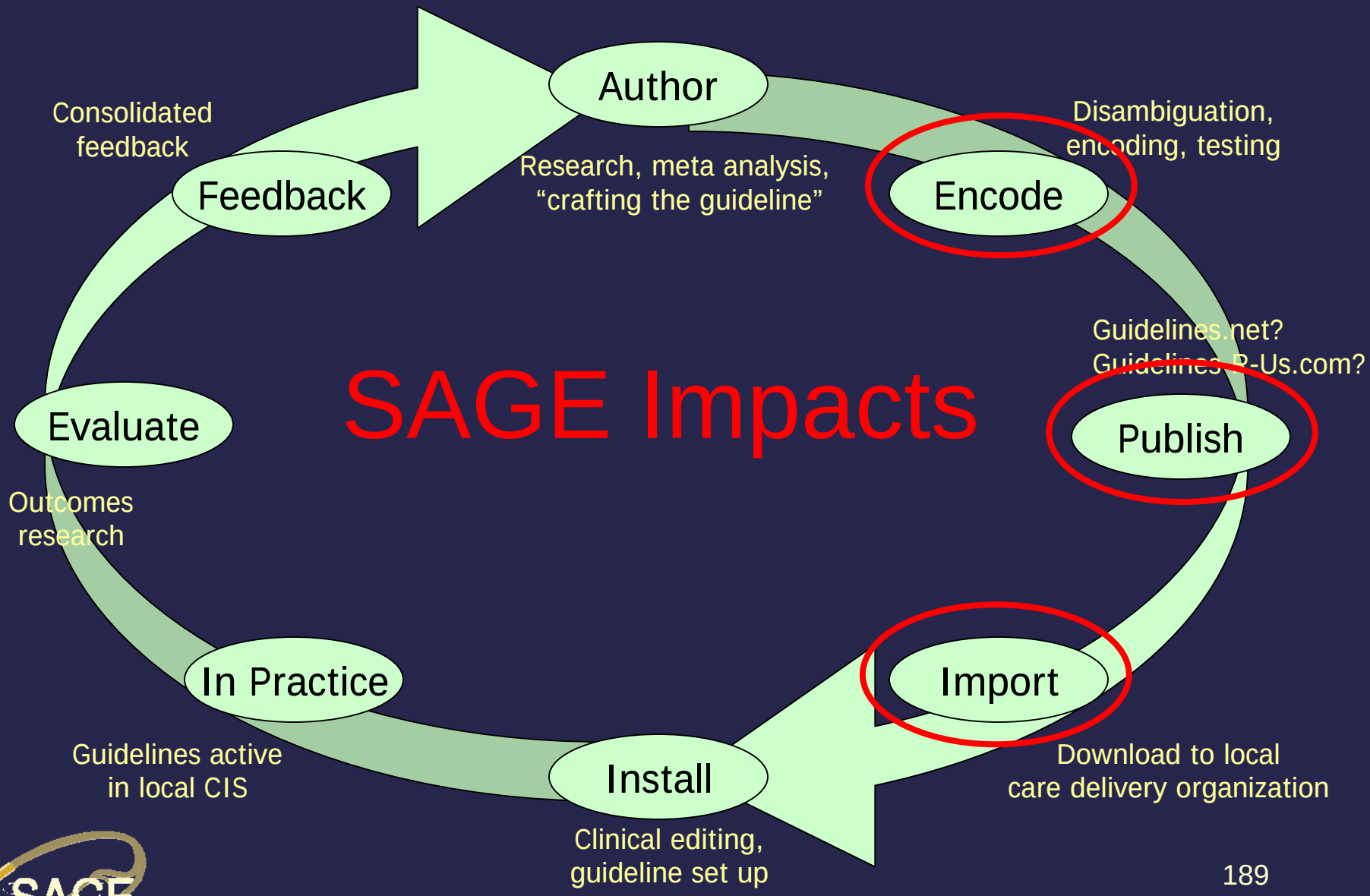
Guideline Lifecycle Vision



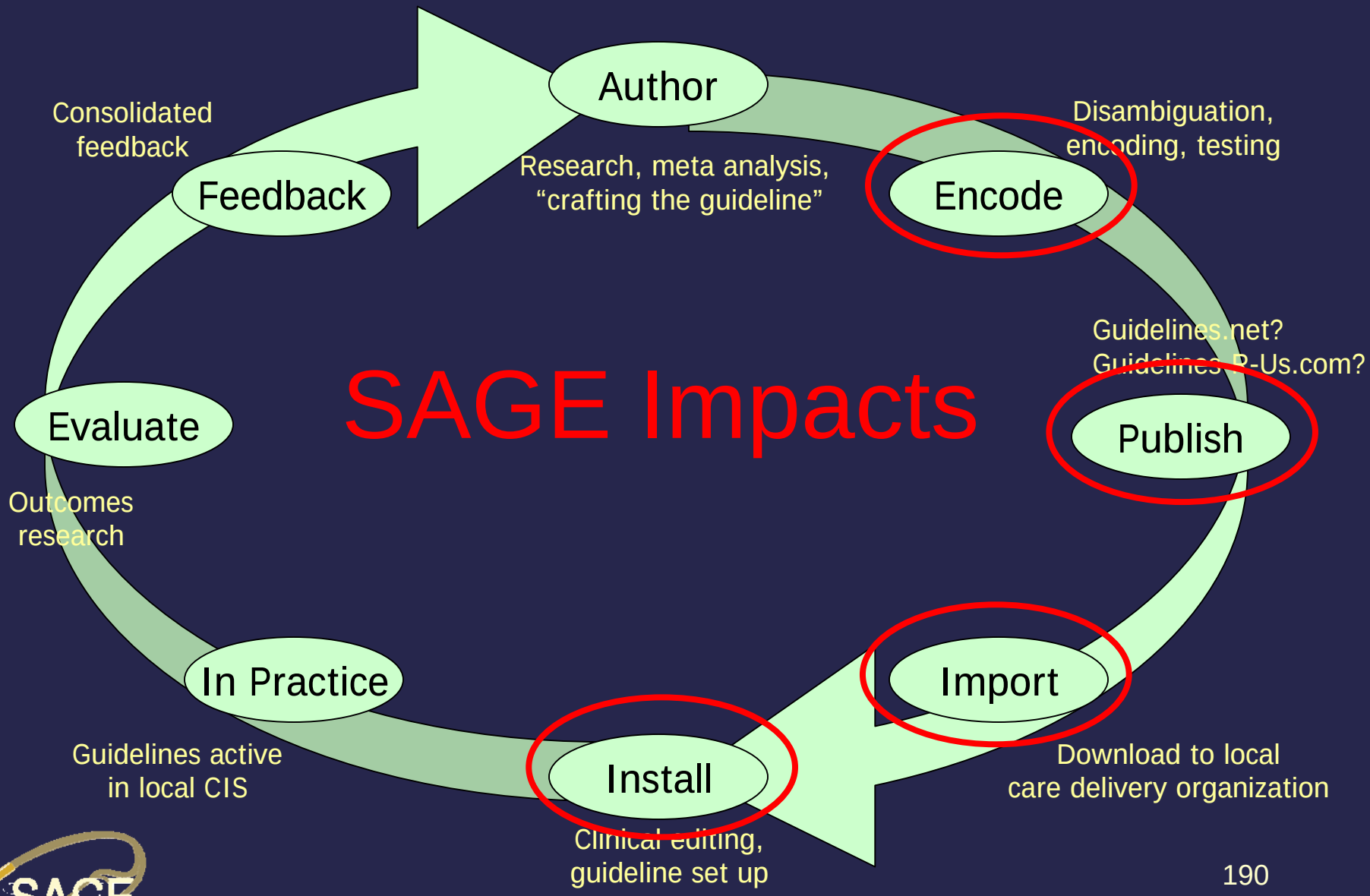
Guideline Lifecycle Vision



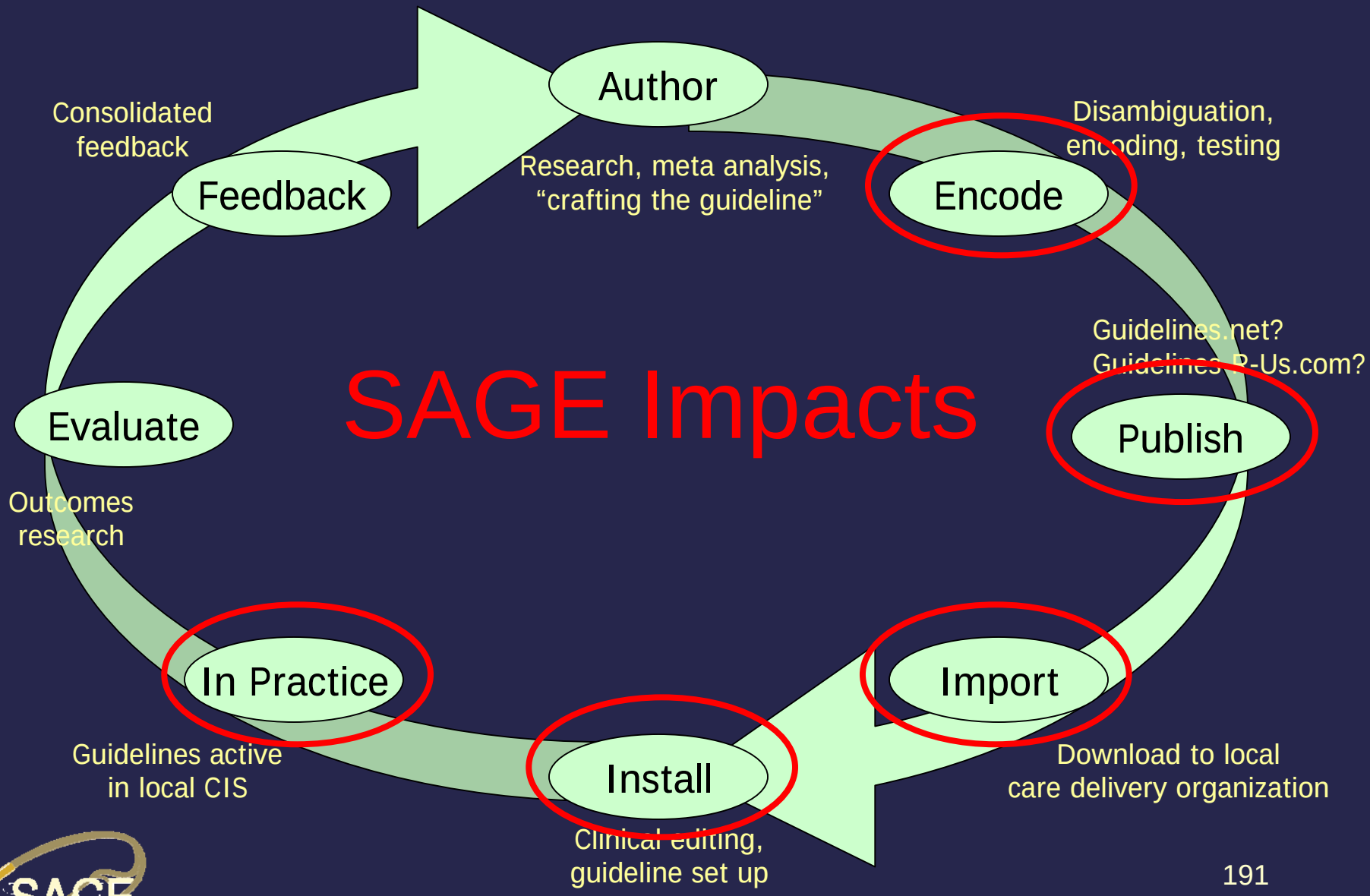
Guideline Lifecycle Vision



Guideline Lifecycle Vision



Guideline Lifecycle Vision



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