Chapter 4
Prerequisites for Learning Clinical Reasoning

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Introduction

To complement the elaboration of the specific method of case-based clinical reasoning (CBCR), this chapter is devoted to general competencies or prerequisites for clinical reasoning that may be acquired in parallel with the acquisition of illness script knowledge from the CBCR method.

Many medical schools design curricula and courses separating preclinical from clinical years, although that tradition has been challenged (Cooke et al. 2010). The designation "preclinical" connotes a curricular responsibility to prepare students for clinical experiences. Developing skills for clinical reasoning is an essential part of a larger, integrated identity that students will need to bring to clinical experiences in order to participate in caring for patients and work in teams. Communication skills are necessary for building rapport with patients, conducting the medical interview, engaging in shared decision-making with patients, eliciting patients' concerns and expectations, discussing clinical cases with colleagues and clinical supervisors, and explaining one's reasoning to others. Aper and colleagues have recently called this "complex competence" (Aper et al. 2014).

Effective clinical reasoning is one of the many competencies students must learn to master. So what can teachers do to promote students' readiness for clinical reasoning before patient care becomes their primary learning activity? In this chapter,

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we will briefly review the traditional educational approaches used to prepare students for immersive clinical experiences and then describe a set of sequential teaching strategies one might consider prerequisites for clinical reasoning. This proposed sequence includes *learning to talk like a physician*, i.e., using the clinical vocabulary; *identifying the clinical problem* to be solved, often called problem representation; *organizing case information* and schema development, i.e., building one's illness script mental repository; comparing and contrasting diagnostic hypotheses, which we will call *contrastive learning*; *identifying discriminating information* for hypothesis-driven inquiry; and *diagnostic verification* to enrich one's mental repository for use in clinical reasoning.

Preparing students to act in clinical rotations and to become involved with clinical reasoning and decision-making in practice is done in medical schools in very different ways, varying from virtually no practice with clinical reasoning to extensive training in lecture settings or small groups, using real or standardized patients, or with written or electronic cases. Traditionally, most medical schools require students to participate in introductory courses designed to teach clinical skills, such as communicating with patients, the medical interview, the physical examination, and clinical reasoning. Some of these courses are described in the literature (LaRochelle et al. 2009). The most common approach involves a longitudinal series of small groups using problem-based learning methods and simulated clinical cases (paper, electronic, or video recorded) or standardized patients to introduce clinical skill or reasoning content and provide opportunity for practice and discussion (Barrows and Tamblyn 1980). More recently, web-based learning and virtual patient encounters by simulation have been introduced to supplement small group experiences (Cook et al. 2010; Kim and Kee 2012). Another common approach is "transition to clerkship" courses designed as an intensive immersion experience for students just prior to beginning their first clerkship (Jacobson et al. 2010; O'Brien and Poncelet 2010). Common content areas include preparation for participation in clinical activities (including clinical reasoning), roles and expectations of students, advice from senior students, professionalism, stress management, and procedural skills.

Underlying any specific model of teaching and often quite implicit is the general purpose of the preparation for clinical reasoning in practice. The six components of this purpose outlined above constitute a general framework that may be addressed in any form of preparatory education. To be able to adequately contribute to the reasoning process of clinical teams, students must be prepared with a *clinical vocabulary*, with the ability to create clinical *problem representations*, with a foundational *illness script mental library*, and with habits of *contrastive learning*, *hypothesis-driven inquiry*, and *diagnostic verification.*

Clinical Vocabulary

Along with learning to think like a physician, medical students learn to talk like physicians. As with all knowledge communities, language is a defining element. The knowledge community of medicine is no exception. The best example of this phenomenon is the admonition to teach students to converse with patients in lay language familiar to the patient and "avoid medical jargon." Yet, when physicians talk together while trying to make sense of a clinical problem or determine the correct diagnosis, they do so using language specific to the practice of medicine. Why is this? There are several reasons why physicians among themselves must use medical terminology. First, numerous medical concepts, be they morphological structures, biochemical or physiological processes, disease entities, procedures of investigation, or medications, simply have no efficient non-jargon wordings ("acromion," "pernicious anemia," "osmosis," "Weber and Rinne hearing tests"). Next, verbal labels are powerful for summarizing combinations of features that would otherwise require extensive explanation ("toxic shock," "Cushing's syndrome"). Finally, medical vocabulary serves the uniformity of information exchange among professionals. While patients may express similar complaints in many different ways, medical terminology serves this uniformity. The outside world may sometimes view this communication among medical professionals as mysterious, ritualized, deliberately secretive to protect the profession as a closed community, and unnecessary, but the truth is that medical vocabulary is indispensible for efficient communication and safe care. Students simply must get acquainted with it.

Preclinical education introduces and reinforces language used to describe core science concepts in order to develop a shared understanding of the pathophysiological basis of disease. Similarly, learning the meaning of words that physicians assign to patients' stories of their illnesses is a prerequisite for learning clinical reasoning. Why is this important? By analyzing transcripts from medical students' and experienced physicians' oral case presentations, Bordage and colleagues have shown that the "think-aloud" discourse patterns of clinicians who eventually arrived at the correct diagnosis used language structures representative of a broad and deep understanding of the clinical problem (Bordage et al. 1997; Bordage and Lemieux 1991). Specifically, those physicians with greater diagnostic competence translated specific clinical features into abstract semantic qualifiers, which facilitated their ability to abstractly define the clinical problem that needed to be solved. Semantic qualifiers are adjectives or adverbs that represent an abstraction of the situational clinical findings (Chang et al. 1998). Examples of semantic qualifiers are shown in the third column of Tables 4.1 and 4.2. One small study among third-year medical students completing standardized patient examinations noted that students who used semantic qualifiers during case presentations as compared to those who simply reported the patient's signs and symptoms demonstrated stronger diagnostic competence (Bordage et al. 1997).

Importantly, training students to use semantic qualifiers in describing the patient's chief complaint and history of present illness is likely to improve their recollection of findings at a later moment, but not necessarily the accuracy of reasoning. Nendaz and Bordage were able to show that second-year medical students could learn to use semantic qualifiers to describe case features. The use of semantic qualifiers was associated with better case information recall but not with better diagnostic accuracy (Nendaz and Bordage 2002). Thus, learning how to talk like physicians should be viewed as a prerequisite condition for developing diagnostic reasoning competence, which in itself requires more. Teachers can encourage preclinical students to begin learning and using the vocabulary of such a semantically driven discourse.

Using a clinical example to illustrate the translation of a patient's story from lay language to semantic qualifiers, consider the following brief clinical history as conveyed by the patient:

> Alicia A. is a 55 year old woman who for the past 2 months has had stiffness of her hands on awakening each morning that lasts for 1–2 hours. She has felt weak and fatigued on several occasions. She has noticed swelling of both wrists and pain when attempting to make a fist. At first, the stiffness didn't bother her. Now, as a basic scientist with an active experimental laboratory, she is having difficulty using micro-pipettes to create her cell cultures.

Alicia becomes "female"; 55-year-old becomes "middle aged"; 2 months becomes "chronic"; stiffness on awakening each morning that lasts for 1–2 h becomes "morning stiffness" (as specifically defined and diagnostically meaningful in the field of rheumatology); weak and fatigued on several occasions become "recurrent, systemic"; both wrists become symmetrical small joints; and difficulty using micro-pipettes becomes "moderately severe." Translated using semantic qualifiers, the story becomes:

> A middle aged female presents with a chronic, recurrent, moderately severe systemic illness characterized by fatigue and morning stiffness in bilateral, symmetrical small joints of the hands.

When introducing new clinical cases for students' consideration, teachers can write the patient's history using common or "lay" language descriptions, similar to the way patients most often portray their stories, and then ask students to translate the case findings into abstract terms. Further, students' review of these clinical histories related to the patient's reason for the visit can be structured to assure thoroughness (Hasnain et al. 2001). A clear focus on and thoroughness of inquiry about the chief complaint early in the patient interview has been associated with stronger diagnostic competence (Hasnain et al. 2001). To encourage students to form strong habits for thorough exploration of the chief complaint, preclinical students may benefit from practice in building their clinical vocabulary with a structured format focused on the basic semantic attributes of the reason for visit and history of present illness: onset, site or location, severity, course or chronology, context including setting and patient characteristics, and aggravating or alleviating factors (Chang et al. 1998; Nendaz and Bordage 2002; Skeff 2014). Table 4.1 shows how a patient's history, described using lay terms, is translated to the medical vocabulary.

In some cases, the abstract translation may be obvious, and, through discussion, students will reach consensus quickly, with or without guidance. In other instances,

Table 4.1 Translation of a patient's history using semantic qualifiers (A)

Structured inquiry of reason for visit	Patient's story described using lay terms	Abstract translation using semantic qualifiers
Symptom onset	"At first the stiffness didn't bother"	Gradual, progressive
Symptom site/location	"Stiffness of her hands"	Small joints, symmetrical
Symptom severity	"Stiffness on awakening lasting 1–2 h," "difficulty using micro-pipettes"	Moderate to severe morning stiffness
Symptom course/ chronology	"2 months"	Chronic
Context/patient characteristics	"55-year-old," "Alicia"	Middle-aged female

the meaning assigned to abstract vocabulary terms will come with greater experience and may be context specific. For example, when does an acute problem become subacute or chronic? When does an oligoarticular problem become polyarticular? Students will need to learn the importance of clarifying the meaning of specific words when discussing clinical cases to facilitate a shared understanding of the clinical problem.

Clinical cases illustrating limb or joint problems lend themselves nicely to learning the meaning of proximal versus distal, symmetrical versus asymmetrical, axial versus appendicular, and mono- versus oligo- versus polyarticular joint complaints. Other clinical presentations, such as those of many cardiovascular, renal, or neurological problems, are typically general or systemic in nature and defining the symptom site is more difficult. Students should be encouraged to recognize and name symptoms of a systemic nature such as fatigue, malaise, or confusion.

A second clinical case illustrates this difference:

> Robert is a 28 year old male brought by his friends to the emergency room after he collapsed during the initial part of his first soccer match. His friends report loss of consciousness of about 30 seconds. Robert reports difficulty breathing, especially when lying down. He has experienced mild shortness of breath when exercising ever since he can remember, but his symptoms now are a lot worse. In retrospect, his exercise tolerance has been declining for the past 9–12 months. He used to be able to do almost anything he wanted but now notices that he gets quite breathless after only a flight of stairs. On two occasions about 4 months ago he had to stop walking up stairs because of chest pain, which scared him. He describes the chest pain as tightness in the middle of his chest that never lasts longer than a minute and goes away with rest.

Table 4.2 illustrates the semantic transformation for this case. Using a similarly explicit approach, Skeff emphasizes the *chronology* of the present illness as a way of making sense out of a complex history of present illness. In this approach, *time* is the core structural element ("overtly identifying times when symptoms appeared or changed"). Advantages of this approach include attending to subtle or puzzling changes in the presentation and finding clues to the pathophysiological process, neither ignoring nor overemphasizing specific symptoms (Skeff 2014).

Table 4.2 Translation of a patient's history using semantic qualifiers (B)

Structured inquiry of reason for visit	Patient's story	Abstract translation using semantic qualifiers
Symptom onset	"He collapsed," "about 30 seconds," "chest tightness, never longer than a minute"	Sudden
		Episodic
Symptom site/location	"Loss of consciousness"	Systemic or constitutional
	"Difficulty breathing"	Respiratory/cardiovascular
Symptom severity	"(Declining) exercise tolerance" "quite breathless after a flight of stairs"	Moderate to severe
Symptom course/chronology	"Declining for the past 9–12 months," "used to be able to do almost anything he wanted"	Chronic, progressive
Context/patient characteristics	"28-year-old," "Robert"	Young male
Aggravating/alleviating factors	"Goes away with rest"	Resolves

Problem Representation

Once students have started to learn the vocabulary physicians use to describe patients' clinical concerns, they will be ready to begin using these words to formulate the clinical problem that the case requires them to solve. This clinical problem formulation is called the problem representation. A problem representation combines the situational information about the patient with the clinician's knowledge to create a structured and actionable description of the problem (Feltovich and Barrows 1984; Gruppen and Frohna 2002).

Constructing a problem representation involves transformation of a patient's specific symptoms and signs into a conceptualization—or representation—of the problem using semantic qualifiers. At this stage, the words reflect meaning the clinician assigns to the case features in relationship to temporal and potential causal relationships between them (Auclair 2007). In other words, students move beyond knowing the words used to describe specific case features to assigning meaning to the words in relationship to case findings—from remembering to understanding—from learning vocabulary to using the vocabulary to represent the clinical problem.

In clinical reasoning, the step of constructing a problem representation occurs between data acquisition and hypothesis generation (Chang et al. 1998). Abstract semantic qualifiers are used to "build a global sense or representation of the problem before tackling possible diagnostic solutions" (Nendaz and Bordage 2002). The problem representation then triggers activation of medical knowledge from long-term memory in the form of plausible diagnoses for the specific case under consideration. Clinicians then purposefully direct further data gathering in relationship to comparing and contrasting diagnostic hypotheses under consideration. Diagnostic accuracy is associated with more thorough and relevant problem representations (Chang et al. 1998).

Generating a problem representation is often an unconscious process (Bowen 2006). Teachers can make this step in the reasoning process explicit by asking students, “what problem are we trying to solve?” Although students at an early stage of learning do not have enough clinical experience to actually solve the clinical problem, students can develop the habit of using clinical vocabulary to construct general problem representations. Feedback on students’ problem representations should promote appropriate abstraction of case features using semantic qualifiers and identifying the key attributes—onset, site, severity, chronology, and context—when describing the nature of the clinical problem based on the chief complaint and history of present illness.

Returning to the examples above, the problem representation in Alicia’s case could be:

> a middle-aged female with a chronic, gradually progressive symmetrical oligoarticular process involving small joints characterized by moderate to severe morning stiffness.

Robert’s problem representation might be:

> young male with sudden onset of brief, self-limited syncope in the setting of chronic, progressive dyspnea and episodic chest tightness that resolves with rest.

Note in the second example the introduction of additional medical terminology, syncope and dyspnea, that experienced clinicians would use to assign meaning to Robert’s problem.

For early clinical learners, we recommend practice with straightforward or typical clinical presentations. Yet, clinical problems are often complex, ill-defined, and ambiguous. In such instances, more than one problem representation simultaneously is possible. Teachers should encourage students to generate appropriate problem representations that may emphasize different key attributes of the case and therefore trigger a broader, yet still plausible set of diagnostic hypotheses for consideration.

Students at this stage of learning often want to know if their problem representations are right or wrong. It is important to point out that construction of a problem representation is an early clinical reasoning step that helps the clinician consider a plausible set of diagnostic hypotheses relevant to the clinical presentation. Each clinician will have her own approach to this conceptualization process influenced by clinical experience. Students should learn that problem representations are not “right or wrong,” just “better” when all relevant attributes are addressed using the appropriate semantic qualifiers for the specific clinical problem. Finally, students are often encouraged to summarize their patient’s problem at the end of a case presentation. These one-sentence summaries are often called summary statements or assessment statements for a particular patient. These statements are not the same as the problem representation and serve very different purposes in the clinical reasoning process. The problem representation is a more generic formulation of the type of clinical problem to be solved and occurs *early* in the data-gathering process. As further data are purposefully gathered to sort through the diagnostic hypotheses triggered by the problem representation, a more complete and specific picture of the patient's problem is created along with a narrowed plausible differential diagnosis. The summary or assessment statement formulation serves to synthesize these specific characteristics for this patient's problem and sets up a discourse about clinical management or diagnostic testing. Table 4.3 illustrates this process for Robert's clinical presentation. Note how hypothesis-driven inquiry reveals additional clinical information (shown in italics).

Illness Script Mental Repository

Once students have a certain fluency with clinical vocabulary and have learned to conceptualize patients' problems using semantic qualifiers, teachers can introduce an additional structure to help students consider features of a typical diagnosis that includes additional knowledge experienced physicians store in long-term memory. Students will learn to integrate foundational science concepts and pathophysiology with the findings from the clinical history, physical examination, and diagnostic testing.

One format used to describe physicians' mental representations of coherent, causal clinical knowledge used in clinical reasoning is the *illness script* (Custers 2015), first described by Feltovich and Barrows (1984). Illness scripts develop with clinical experience. Custers summarizes the common components of illness scripts as:

> (1) high-level, precompiled, conceptual knowledge structures, which are (2) stored in long-term memory, which (3) represent general (stereotyped) event sequences, in which (4) the individual events are interconnected by temporal and often also causal or hierarchical relationships, that (5) can be activated as integral wholes in appropriate contexts, that (6) contain variables and slots that can be filled with information present in the actual situation, retrieved from memory, or inferred from the context, and that (7) develop as a consequence of routinely performed activities or viewing such activities being performed; in other words, through direct or vicarious experience. (Custers 2015)

Most students in the early years of medical school will not have enough direct or vicarious experience to have begun forming their own full-fledged illness scripts in memory. Nevertheless, as they learn about typical presentations of clinical cases, rudimentary illness scripts begin to form. Junior students with personal experience with an illness may possess a script for it (e.g., "flu" or "motion sickness"). When provided a schema structure that explicitly elicits components of illness scripts, students can organize information about those clinical cases into the structure of illness scripts, taking the vocabulary they are learning and "placing" it in a schema about a particular "typical or exemplar" clinical diagnosis.

Table 4.3 Evolution of early problem representation to summary statement in the diagnostic reasoning process

Patient's history	Problem representation	Triggered diagnostic hypotheses	Hypothesis-driven inquiry
Robert is a 28-year-old male brought by his friends to the emergency room after he collapsed during the initial part of his first soccer match	Young active male with sudden collapse	Cardiac etiology Neurologic etiology Intravascular volume loss from trauma Pulmonary embolism	Did he lose consciousness?
His friends report loss of consciousness of about 30 s	Young active male with sudden collapse and loss of consciousness	Syncope: cardiac versus neurologic etiology Seizure	Was there any involuntary motor activity? Any postictal symptoms?
No one observed any jerking movements; when he regained consciousness, he was fully alert and aware	Young active male with syncope	Syncope of cardiovascular or neuro-cardiogenic origin Vasovagal syncope	Did he experience any other cardiovascular or neurologic symptoms?
Robert reports difficulty breathing, especially when lying down	Young active male with syncope, dyspnea, and orthopnea	Aortic stenosis Hypertrophic obstructive cardiomyopathy Idiopathic pulmonary arterial hypertension Pulmonary embolism	What is the chronology of his respiratory distress?
He has experienced mild shortness of breath when exercising ever since he can remember, but his symptoms now are a lot worse. *He has not had any palpitations*	Young active male with syncope in the setting of orthopnea and chronic progressive dyspnea	Aortic stenosis Hypertrophic obstructive cardiomyopathy Idiopathic pulmonary arterial hypertension Pulmonary embolism	Are there any other cardiovascular symptoms with a similar chronology?
In retrospect, his exercise tolerance has been declining for the past 9–12 months. He used to be able to do almost anything he wanted but now notices that he gets quite breathless after only a flight of stairs	Young active male with syncope in the setting of orthopnea, chronic progressive severe dyspnea, and declining exercise tolerance	Aortic stenosis Hypertrophic obstructive cardiomyopathy Idiopathic pulmonary arterial hypertension Recurrent pulmonary emboli	Does he have chest pain?

(continued)

Table 4.3 (continued)

Patient's history	Problem representation	Triggered diagnostic hypotheses	Hypothesis-driven inquiry
On two occasions about 4 months ago he had to stop walking upstairs because of chest pain, which scared him. He describes the chest pain as tightness in middle of his chest that never lasts longer than a minute and goes away with rest	Young active male with syncope in the setting of orthopnea, chronic progressive severe dyspnea, declining exercise tolerance, and typical exertional chest pain	Aortic stenosis Hypertrophic obstructive cardiomyopathy Idiopathic pulmonary arterial hypertension Recurrent pulmonary emboli	Does he have any risk factors for pulmonary embolus?
He has not traveled recently (no prolonged immobility), has no history of blood clots, and has no history of malignancy	Young active male with syncope in the setting of orthopnea, chronic progressive severe dyspnea, declining exercise tolerance, and typical exertional chest pain without risk factors for pulmonary embolism	Aortic stenosis Hypertrophic obstructive cardiomyopathy Idiopathic pulmonary arterial hypertension	Does he have preexisting diagnoses (comorbidities) that would make any of the diagnoses under consideration more or less likely?
He remembers he had a heart murmur when he was a child and that when his parents were alive he used to get very painful monthly injections. When he was 18 years old, he took a daily "penicillin" pill, but he has not taken anything for years	Young active male with sudden-onset syncope, chronic progressive dyspnea with orthopnea, intermittent typical chest pain, progressive fatigue, and an unclear history of a heart murmur as a child	Aortic stenosis, probable congenital bicuspid valvular disease Hypertrophic obstructive cardiomyopathy Idiopathic pulmonary arterial hypertension	Hypothesis-driven physical examination is performed
Hypothesis-Driven Physical Examination: Temp of 37.3 °C, HR 125, RR 30, BP 100/50, and oxygen saturation of 89% on room air; JVP is elevated to the angle of the jaw when sitting 45° from supine; carotid pulses diminished with delayed upstroke bilaterally; chest palpation with parasternal heave and precordial thrill; auscultation reveals a 4/6 systolic ejection murmur heard best at the right second intercostal space that does not change with Valsalva maneuver, loud S2, and S3 heard at the apex; peripheral pulses are 1+ and symmetrical; lung auscultation reveals bilateral crackles to level of scapulae; the liver is palpable 3 finger breaths below the right costal margin; skin is cool without cyanosis; 2 + ankle edema noted bilaterally; neurological exam is normal			

(continued)

Table 4.3 (continued)

Patient's history	Problem representation	Triggered diagnostic hypotheses	Hypothesis-driven inquiry
Summary Statement: A 28-year-old male with sudden-onset syncope, moderate to severe dyspnea with orthopnea, in the setting of intermittent chest pain typical of angina, progressive fatigue, and an unclear history of a heart murmur as a child. Exam suggests heart failure. Murmur noted on cardiac auscultation and carotid pulses (*pulsus parvus et tardus*) most suspicious for aortic stenosis. He is at risk for subacute bacterial endocarditis. With a low-grade fever, this should be pursued. A diagnostic echocardiogram will likely be the best approach for distinguishing aortic stenosis from hypertrophic obstructive cardiomyopathy and idiopathic pulmonary arterial hypertension, which are less likely. The echocardiogram would also detect the suspected congenital bicuspid aortic valve abnormality			

Table 4.4 Illness script worksheet

	Attributes	Typical findings
Enabling conditions	Age, sex, race, ethnicity	
	Family history, genetics	
	Habits, exposures, medications	
	Nested comorbidities if any	
Pathophysiological fault		
Clinical consequences	**Onset**	
	Site	
	Severity	
	Chronology	
	Physical exam findings	
	Laboratory findings	
	Imaging findings	

Table 4.4 shows the expanded version of Tables 4.1 and 4.2 as a worksheet for students that provides structure for building knowledge storage in a general mental framework typical of illness scripts. It includes the categorized components of the illness script—enabling (predisposing) conditions, (pathophysiological) fault, and (clinical) consequences—with space for students to record typical features concisely. For *enabling conditions*, students should consider age, sex, race, ethnicity, genetics, nested comorbidities (existing diagnoses with their own illness scripts associated at a lower hierarchical level with the current illness script), environmental exposures, habits (e.g., smoking), and medications; for *pathophysiological fault*, the goal is to integrate science learning with clinical case information to address mechanisms of insult or injury, such as hemodynamic regulation, neuro-regulation, inflammatory process, infectious process, genetic mutation, and metabolic disorder, among others; for *clinical consequences*, the schema builds from the vocabulary training, addressing the chief complaint and history of present illness (onset, site, symptom severity, course/chronology) and adding physical examination findings, laboratory findings, imaging findings, and findings from diagnostic procedures. Of course, not all diagnoses will have information in all of these schema "fields,"

creating opportunities for teachers to emphasize the diagnostic utility of testing and procedures.

Students must gradually build in their long-term memory a mental repository of illness scripts that become readily available for comparison at any new encounter with a patient. This requires elaboration of many cases, with and without guidance. This mental repository can only be built in a curriculum that provides many own or vicarious encounters with patients, real or simulated, and that stimulates students to study and reflect on these cases.

Contrastive Learning

Contrastive learning "involves prompting the learner to explicitly search for similarities and differences between problems" (Ark et al. 2007). Applying the concept of analogical transfer whereby learners address novel problems with strategies used to solve similar problems previously, Ark and colleagues demonstrated superior diagnostic accuracy for contrastive learning compared to traditional serial learning. They trained novices to identify key features of a series of typical abnormal electrocardiograms (ECG), to compare and contrast abnormal features of the initial ECG with a normal ECG and with an ECG typical of a plausible alternative diagnosis. The goal was to assist students with learning the critical features that discriminate between categories by having them intentionally consider similarities and differences between pairs of abnormal ECG exemplars. When compared to novices instructed to learn key features of exemplar ECGs in a serial, non-contrastive way, students instructed in a contrastive learning strategy identified the correct ECG diagnosis significantly more often. Others have recommended using a compare and contrast approach to learning with a focus on deep learning of a limited number of prototypical clinical presentations related to a single problem representation in order to create strong anchors in memory (Bordage 1994).

Thus, the next step in preparing early medical students for clinical reasoning involves contrastive learning. Once students have learned to develop schemas for the clinical cases under discussion, teachers can introduce the concept of the differential diagnosis and the process of comparing and contrasting a limited number of diagnostic considerations. For any given problem representation formulated from information revealed early in the clinical case, at least two plausible diagnostic hypotheses are selected for comparison. Preselection, as opposed to student selection, of the diagnoses to be considered is important at this stage of learning. Diagnostic possibilities must be realistic and easily distinguishable. Thus, for Alicia's case, one would choose to have the students compare the exemplar case of rheumatoid arthritis with that of osteoarthritis as shown in Table 4.5. Once the schemas for individual clinical presentations are described, putting the two side by side as shown allows students to compare and contrast the differences and learn to identify the distinguishing features.

Table 4.5 Contrasting competing illness scripts

	Example of a problem representation		
	A middle-aged female with a chronic, gradually progressive symmetrical oligoarticular process involving small joints characterized by moderate to severe morning stiffness		
Exemplar diagnosis		1- Osteoarthritis	2- Rheumatoid arthritis
Enabling conditions	Age, sex, race, ethnicity	Over 50 yrs.; either sex	30–60 years, F:M ratio 3:1
	Family history, genetics	+/− family history	+ family history; shared epitope, HLA-DRB1
	Habits, exposures, medications	None	Smoking
	Nested comorbidities	None	Coronary artery disease
Pathophysiological fault		Mechanical, degenerative; cartilage breakdown and subsequent bone hypertrophy	Inflammatory, immunologic; synovitis, pannus and subsequent erosion of juxta-articular bone
Clinical consequences	**Onset**	Gradual	Gradual
	Site	Small, large joints; appendicular; polyarticular; involves DIP	Small, large joints; appendicular; polyarticular; usually spares DIP
	Severity	Mild	Moderate
	Chronology	Chronic persistent	Chronic persistent
	Exam findings	Boney enlargement of joint; mild tenderness if any	Warmth; erythema; tenderness; swelling; occasional rheumatoid nodules
	Laboratory findings	None	Elevated ESR; rheumatoid factor anti-CCP
	Imaging findings	Sclerosis of bone under cartilage; joint space narrowing; osteophytes	Erosive polyarthritis; joint space narrowing

Hypothesis-Driven Inquiry

In traditional medical education, preclinical medical students learn components of the physical examination and then learn to assemble these components into a logical sequence necessary for the head-to-toe examination of any patient (Nendaz and Bordage 2002; Yudkowsky et al. 2009). Except perhaps for the purpose of documenting a baseline examination in a healthy person, this approach to learning the physical examination does not promote its purpose as a data-gathering step in the clinical reasoning process. Such decontextualized learning delays comprehension of the significance of abnormal examination findings as discriminating features in the diagnostic process. As Yudkowsky and colleagues suggest, "students do not learn to appreciate how an abnormal finding would appear or what it might mean." These authors studied an alternative approach designed to support contextual learning by embedding instruction in physical examination maneuvers within diagnostic reasoning tasks. The approach emphasizes students' abilities to anticipate which examination maneuvers will help discriminate between diagnostic considerations and to recognize diagnostically useful examination findings. A useful guide is available for implementing this method (Nishigori et al. 2011).

Similarly, Hasnain and colleagues studied the relationship between history-taking behaviors, semantic versus symptom-driven discourse, and diagnostic accuracy. Four interviewing behaviors were associated with high diagnostic accuracy: thorough exploration of the patient's chief complaint early in the clinical encounter, asking questions in close proximity (illustrative of a line of reasoning about a diagnostic hypothesis), asking patients to provide further clarifying information, and summarizing information gathered during the interview. The authors describe these behaviors as "purposeful or hypothesis-driven inquiry" (Hasnain et al. 2001). Table 4.3 illustrates this process for Robert's clinical problem.

Diagnostic Verification

Diagnostic verification is defined by Kassirer et al. as "the process in which one or more hypotheses are accepted as sufficiently valid to permit further decision making" (Kassirer et al. 2010) and is referred to by Gruppen and Frohna as evaluation ("guiding the acquisition of additional information and, eventually, the decision to stop the cycle and move on to action") (Gruppen and Frohna 2002). We suggest including in the definition of diagnostic verification *all actions that lead to confirmation of the correctness, to the extent possible, of the final diagnosis* even if only to learn from a case and to store a case in memory, contributing to an enriched personal repository of illness scripts. As the skill of clinical reasoning is highly dependent on this repository, any solidification should enhance this skill. In clinical training, given duty hour restrictions, short patient stays, and frequent patient handovers, diagnostic verification—finding out about the consequences of one's diagnostic reasoning process—does not always happen and may need active effort on top of regular clinical duties. Preclinical students should start developing the habit of diagnostic verification, as that will enhance the retrieval of patient cases and enriched illness scripts from long-term memory in the future.

How Does the CBCR Method Address These Prerequisites?

While this chapter is not focused on the description of the CBCR method, it is useful to consider to what extent the CBCR method, described more extensively in Part II, reinforces the prerequisite skills for clinical reasoning. Table 4.6 shows how that is the case.

In summary, introducing concepts associated with strong clinical reasoning performance early in medical school, described here as prerequisites for clinical reasoning, provides an alternative approach to preparing students for their immersive clinical experiences. Learning the clinical vocabulary physicians use when presenting and discussing clinical cases prepares students to become members of the knowledge community of clinical medicine. Learning to translate patients' chief complaint and history of present illness into abstract summaries using semantic qualifiers prepares students to describe thorough and accurate problem representations, an important step in diagnostic reasoning. Abstracting and recording key clinical information into a schema aligning with illness script formation helps students to associate key clinical attributes with pathophysiological explanations of disease processes in the context of clinical cases and store these as units in long-

Table 4.6 Relating the prerequisites to the CBCR method

Prerequisite element	Relationship to CBCR
Clinical vocabulary	As a method that requires active oral participation in reasoning by all students, CBCR provides excellent opportunities to practice the use of medical vocabulary
Problem representation	Many CBCR cases introduce the encounter in the patient's words and have as a first assignment for students "what is, in your own words, the reason for the encounter?" or "what is the chief complaint?" Questions like this force students to represent the problem in a structured way, preparing students for creating problem representations using abstract semantic qualifiers
Illness script mental repository	The background of the CBCR method actually is to engage junior medical students in the creation of mental constructs of a limited number of prototypical diagnoses to serve as a framework for early comparing and contrasting of patterns
Contrastive learning	One dominant approach during all CBCR cases is the creation and completion of two-dimensional tables on a blackboard or flipchart, with findings on one axis and diagnostic hypotheses on the other. With plusses and minuses, student groups must continuously contrast the likelihood of diagnoses using findings from the history, physical examination, and tests
Hypothesis-driven inquiry	A feature of the CBCR method is that gradually more information about cases is revealed and students are asked to respond to new information by suggesting new hypothesis or new information needed. By nature, CBCR cases stimulate hypothesis-driven inquiry
Diagnostic verification	As all cases eventually end with one diagnosis, CBCR cases naturally include diagnostic verification. The drawback is that students do not need to be stimulated to pursue that information. Training of that habit is more logical in the clinical environment than in the classroom setting

term memory. Comparing side-by-side schemas for plausible diagnostic considerations related to a specific case and problem representation reinforces for students the important step of contrastive thinking. Learning to consider the history and physical examination as important steps in data acquisition that help physicians to discriminate between diagnostic possibilities and pursuing diagnostic verification bring all of these prerequisites together to prepare students for application of these skills as they develop competence in clinical reasoning.

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