Modelling medical diagnostic processes

Thesis

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Modelling Medical Diagnostic Processes

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Consultation #1

Chief complaint
Mrs A.F. is a 42 year old lady, who presents with right sided back pain.

Back pain History
The pain is severe, making it difficult to do housework and was present when she woke up on the day of presentation though it did not wake her up. The pain was not relieved by any particular posture nor by paracetamol. The pain was constantly present but no particular movements aggravated it. There was no history of sciatic radiation.

General Information (occupation, social history)
She worked as a secretary till one year previously when made redundant. She is married, though there is a history of recent marital disharmony.

Past Medical History
Her previous medical history includes a "prolasped intervertebral disc" 6 years previously, treated only by her own GP, which responded to a week bed rest. Four years previously she was depressed for a period of 6 months. One year ago she was discovered to have an absent left kidney after an intravenous urogram (IVU) ordered after a bout of haematuria (blood in the urine) during a urinary tract infection. These investigations were performed by the consultant surgeon she was referred to by her GP.

Physical Examination
On examination she had tenderness in the right loin, no disc tenderness, mild spasm in the low lumbar region, and no neurological signs in the legs. Straight leg raising (SLR) was 80 degrees on the left, 90 degrees on the right. Abdominal examination was normal.

Investigations
After the pain did not respond to analgesia, investigations to exclude renal pathology - a stone in particular - were performed. These included another IVU and a cystoscopy. No abnormalities were discovered. She was noted to be midly depressed and guilty about the problems she and her husband were having in their marriage.

Diagnosis #1 and Management
Her symptoms were put down to non specific mechanical low back pain and she was provided with a corset.
Consultation #2

Chief Complaint
Two years later she developed a further attack of similar right sided low back pain.

Physical Examination.
This time SLR was reduced to 30 degrees on the affected side. Her ankle jerks (reflexes) were noted to be brisk.

Diagnosis #2
A diagnosis of "90% psychological overlay, 10% non specific low back pain" was made.

Consultation #3

Chief Complaint
The symptoms (from consultation #2) persisted a further 3 months.

Physical examination
Another referring doctor found the left ankle jerk to be diminished and sensation diminished from the mid thigh downwards in both legs.

Diagnosis #3
A provisional diagnosis of a prolapsed intervertebral disc was made.

Investigations
A myelogram was ordered. This shows a lumbar disc prolapse between the fourth and fifth lumbar vertebrae (L4/L5 level).

Management
A laminectomy and discectomy was performed (the offending disc removed) after which all the patient's back symptoms resolved.

General comments on the patient case:
It remains difficult to know precisely what the problem was at the time of presentation picked. She may have had an (early) prolapsed disc all along, though this was not clinically clear cut. Undoubtedly, the matter of her underlying depression complicated matters.

The presentation used in the study was the first one.
APPENDIX A2: INSTRUCTIONS TO SUBJECTS

The subject was first given the following instructions for the first part of the experiment:

Thank you for agreeing to participate in this experiment.

The experiment is run by myself, Laurence Alpay, Ph.D. student at the Open University, with the help of Dr. Mike O'Neil. The purpose of the experiment is to study the medical diagnostic process. I do not have any background in Medicine.

Results will only be used for my research work, and personal details such as your name are kept anonymous. The only information that will be reported include your medical position, and the institution where you work.

The experiment is in 2 parts: first you will be in consultation with a patient (myself), and requested to diagnose her problem. Although you are not presented with the real patient, the case is real. You are asked to think aloud through your reasoning processes, verbalising what you are doing.

The interview covers one single consultation which you should end when you think the time is right. Work in your customary manner, and do whatever you feel is appropriate for the case at hand.

Since you will not examine the patient like you will do in reality, you are asked to be specific about how you will examine the patient. Physical findings will be provided by Mike.

The session is recorded, and will last 15 minutes.

The second part of the experiment will take place after the consultation with the patient, and explained at that point.

If you have any question before starting the first part of the experiment, please ask.
After having completed the first part of the experiment i.e. the consultation with the patient, the subject was given the following instructions for the second part of the experiment:

In the second part of this experiment, you are asked to explain your decisions such as the questions you asked, the investigations you requested etc. The tape is replayed if you wish, to help you recalling what you have said.

The session is also recorded, and will last 20 minutes.

If you have any question before starting the second part of the experiment, please ask.
APPENDIX A3: LIST OF GOALS

The list of goals are given in alphabetic order:

Note:
1. Each goal name has the prefix CHECK attached to it e.g. check_abdominal_xrays to distinguish it from the other slots of the goal.
2. The definition of a goal describes what the physician will ask or do.
3. The corresponding plan for these goals is in appendix A8.

<table>
<thead>
<tr>
<th>NAME OF THE GOAL</th>
<th>DEFINITION OF THE GOAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>abdominal_xrays</td>
<td>(ask for xray of the abdomen to be done)</td>
</tr>
<tr>
<td>accident_back</td>
<td>(ask the patient about any past accident where the back was injured)</td>
</tr>
<tr>
<td>age</td>
<td>(ask the patient what is her age, or the physician has mentioned her age)</td>
</tr>
<tr>
<td>aggravating_factors</td>
<td>(ask the patient if there is anything that makes the pain worst)</td>
</tr>
<tr>
<td>aggravating_relieving_factors</td>
<td>(ask the patient if there is anything that makes the pain worst or better)</td>
</tr>
<tr>
<td>allergies</td>
<td>(ask the patient if she has any allergies)</td>
</tr>
<tr>
<td>appetite_habits</td>
<td>(ask the patient how is her appetite)</td>
</tr>
<tr>
<td>back_pain_history</td>
<td>(take the history of the patient's back pain)</td>
</tr>
<tr>
<td>back_pain_with_waterwork_infection</td>
<td>(ask the patient if she had back pain with her waterwork infection)</td>
</tr>
<tr>
<td>back_xrays</td>
<td>(ask for xray of the back to be done)</td>
</tr>
<tr>
<td>bending_back</td>
<td>(ask the patient to bend)</td>
</tr>
<tr>
<td>bowel</td>
<td>(ask the patient about her bowels)</td>
</tr>
<tr>
<td>cardio_respiratory</td>
<td>(ask the patient about any cardio-respiratory symptoms)</td>
</tr>
<tr>
<td>characteristics_pain</td>
<td>(ask about the characteristics of the pain which define how is the pain)</td>
</tr>
</tbody>
</table>
(ask the patient which medicines she has taken for the pain and/or if she is taking any other medicine)
(ask the patient if she has any water work infection/urinary infection at the moment)
(ask the patient about her children)
(diagnose what wrong with the patient)
(ask the patient about her drinking habits)
(ask the patient how long she had the pain)
(ask the patient if the pain is continue or episodic)
(ask more about if the pain is episodic or continue)
(examine the back of the patient).
(ask the patient about her family i.e. husband, children)
(ask the patient if she feels hot and sweatty)
(ask the patient if she feels fit)
(check the patient's flexion)
(ask the patient to flex her legs)
(ask the patient about her general health)
(ask the patient if the onset of the pain was sudden)
(ask the patient about any gynecology problem)
(take the history of the patient)
(ask for investigations e.g. xrays, samples to be carried out)
(ask the patient about her kidneys)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>kind_of_pain</td>
<td>(ask kind of pain e.g. renal pain)</td>
</tr>
<tr>
<td>location_pain</td>
<td>(ask the patient where is the pain)</td>
</tr>
<tr>
<td>location_pain_more</td>
<td>(ask more about the location of the pain)</td>
</tr>
<tr>
<td>location_previous_pain</td>
<td>(ask the patient where the pain was when she had back pain 4 years ago)</td>
</tr>
<tr>
<td>lower_back_xrays</td>
<td>(ask for x-rays of the lower back to be done)</td>
</tr>
<tr>
<td>medicines_taken</td>
<td>(ask the patient if she has taken any medicines)</td>
</tr>
<tr>
<td>movements_legs</td>
<td>(ask the patient if she can move her legs)</td>
</tr>
<tr>
<td>neurological_examination</td>
<td>(perform a neurological examination)</td>
</tr>
<tr>
<td>number_children</td>
<td>(ask the patient the number of children she has)</td>
</tr>
<tr>
<td>occupation</td>
<td>(ask the patient what is her job)</td>
</tr>
<tr>
<td>other_problems</td>
<td>(ask the patient if there is any other problem)</td>
</tr>
<tr>
<td>pain_with_waterwork_infection</td>
<td>(ask the patient if she had pain with her waterwork infection)</td>
</tr>
<tr>
<td>palpation</td>
<td>(palpate the back)</td>
</tr>
<tr>
<td>palpation_muscle</td>
<td>(palpate the back with focus on the muscles)</td>
</tr>
<tr>
<td>palpation_vertebrae</td>
<td>(palpate the back with focus on the vertebrae)</td>
</tr>
<tr>
<td>past_illnesses</td>
<td>(ask the patient about past illnesses)</td>
</tr>
<tr>
<td>past_medical_history</td>
<td>(take the past medical history of the patient)</td>
</tr>
<tr>
<td>past_operations</td>
<td>(ask the patient about any past operation)</td>
</tr>
<tr>
<td>past_operations_back</td>
<td>(ask the patient about any past operation of the back)</td>
</tr>
<tr>
<td>past_waterwork_infections</td>
<td>(ask the patient about waterwork infection/urinary infection in the past)</td>
</tr>
<tr>
<td>physical_examination</td>
<td>(examine the patient)</td>
</tr>
<tr>
<td>posture</td>
<td>(check how the patient stands)</td>
</tr>
</tbody>
</table>
previous_back_pain: (ask the patient about her previous back pain)

quantity_food: (ask the patient if she eats a lot or not)

radiation_pain: (ask the patient if the pain goes somewhere else i.e. radiates)

radiation_previous_pain: (ask the patient if, when she had back 4 years ago, the pain went somewhere else i.e. radiated)

recent_occupation: (ask the patient what she did the day before)

relieving_factors: (ask the patient if there is anything that makes the pain better)

relieving_factors_more: (ask more about the relieving factors of the pain)

reflexes: (check the reflexes)

reflexes_lower_limbs: (check reflexes of the lower limbs)

results_current_medicines: (ask the patient if the medicines she has taken for the pain has helped)

rotation: (check rotation)

samples: (ask for samples e.g. urine to be done)

severity_pain: (ask the patient how bad is the pain)

similar_pain: (ask the patient if the pain is similar to the previous back pain 4 years ago)

situation_home: (ask the patient how is the situation at home e.g. happy, financial difficulties etc)

sleeping_habits: (ask the patient how does she sleep)

slr: (do a straight leg raising test)

smoking: (ask the patient if she smokes)

social_history: (ask the patient about her social history)

sudden_onset: (ask the patient is the onset of the pain was sudden)

time_sleep: (ask the patient about her sleeping pattern)

touch_toes: (ask the patient to touch her toes)
<table>
<thead>
<tr>
<th>treatment_previous_back_pain</th>
<th>(ask the patient about the treatment she had for her previous back pain event 4 year ago including xrays, tests, physiotherapy etc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>urine</td>
<td>(ask the patient if any thing is wrong with her urine e.g. color, smell)</td>
</tr>
<tr>
<td>urine_sample</td>
<td>(ask for a urinary sample to be done)</td>
</tr>
<tr>
<td>waterwork_infection_problem</td>
<td>(ask the patient about any water work/urinary infection)</td>
</tr>
<tr>
<td>weight</td>
<td>(ask the patient if she has lost or gained weight)</td>
</tr>
<tr>
<td>xrays</td>
<td>(ask for xrays to be done)</td>
</tr>
</tbody>
</table>
This appendix contains a set of glossaries for the low level coding of the protocols coding. Following are the nine lists:

1. Diseases and problems of back pain
2. Symptoms
3. Characteristics of the pain
4. Signs
5. Examination tests
6. Investigation tests
7. Investigation of tests results
8. Treatments for pain
9. Results of treatments

Note:
The category of differential diagnosis (#10) is the same as #1. The results of a treatment (#9) correspond to the patient's response to that treatment: it is either successful and the patient feels better, or the treatment did not work and the patient is still in pain. The list is the same as in treatment along with its result successful or unsuccessful. All the glossaries are by alphabetic order.
1. Diseases and problems of back pain

acute condition
abdominal disease
anaemia
ankylosing spondylitis
apophyseal osteoarthrosis
arthritis
arthritic changes
bacterial infection
bone disease
breast carcinoma
bronchus carcinoma
carcinoma
chronic
coccydinia
cœliac disease
collagen disorder
congenital anomalies
degenerated problems
degenerative problems
degenerative arthritic
disc prolated
duodenal ulcer
fractures
gastro intestinal problems
gynaecological problems
hip problems
hodgkin's disease
inflammatory disease
infection
injuries
kidney carcinoma
kidney problem
kyphosis
lesion
lordosis
lumbar disc prolapsed
lumbar kyphosis
lumbar root lesion
malignancy
mechanical
metabolic disease
metaseses
myelomas (myelomatosis)
muscle strains
muscular pain
osteoarthritis (osteoarthrosis)
osteochondritis
osteomalacia
osteoporosis (osteoporotic)
osteoporosis collapse
neoplastic disease
Paget's disease
pathology obstetrics
pelvic disease
pleurisy
pneumonia
primary deposit
primary of lungs
primary of prostate
prolapsed intervertebral disc
prostatic problems
referred problems
reticuloses
rheumatoid arthritis
sciatica
sciatic scoliosis
scoliosis
secondary (ies)
secondary deposit
secondary of prostate
shingles
slipped disc
spinal stenosis
spinal neoplasms
spondylo arthropathies
spondylolisthesis
spondylosis
sprains
strains
stress fracture
structural
stuck back
thyroid carcinoma
traumas
tumors
tuberculosis (TB) of spine
vascular claudification
vertebral collapse
water work infection

2. Symptoms

acute back pain
backache
back pain
back stiffness
bending
buttock pain
calf pain
chronic back pain
chronic progressive back pain
corset worn for along time
defecation control loss
diarrhoea
digestion symptoms
dysmenorrhoea
extension
gastro intestinal symptoms
gynaecological symptoms
flexion limited
flexion not limited
flexion forward limited
3. Characteristics of pain

An explanation was given to the independent assessor for each of the characteristics

aggravating factors (things that the patient does e.g. sitting and that makes the pain worse)

associated factors (is there anything else associated with the pain e.g. symptom like stiffness)

duration (how long have you had the pain, it is acute or chronic etc)

episodic or continuous pain (is the pain continue or episodic)

location and radiation (where is the pain and does it goes anywhere else)

onset of pain (when did the pain start)

previous similar pain (did the patient experience a similar pain previously)

relieving factors (things that the patient does e.g. lying and that relieves the pain)
severity (mild, moderate, severe)
times of the pain (morning, afternoon, night etc)
previous treatment (did the patient have any previous treatment for the pain)

4. Signs

ability to bend forward and place palms on floor
abnormal lordosis
deformity
lattened lumbar spine
lower limb shorter
limited movements
mobility
muscle spasm
muscular weakness
peripheral pulses present
reduced sensation
straight leg raising
tenderness
tenderness over sacro iliac joints
tendon reflex change

Included in signs are also:

age
job
occupation
old
sex
smell of tobacco smoke
young

5. Examination Tests

abdominal examination
flexion
flexion forward
flexion of the knee
flexion of the hip with knee
lateral flexion
lateral pelvic compression
movements
muscle examination
neurological examination
palpation
palpation of iliac spines
palpation of the kidney
palpation of muscle
palpation of paraspinal
palpation on sacrum
posture
posture of lower limb
posture of the leg length
rotation
sensory examination
sensory examination over saddle area
weaknesses
straight leg raising test

6. Investigation Tests

acid phosphatase
alkaline phosphatase
blood count
blood test
bone scan
CAT scan
ESR test
HLAB27 test
isotope scan
LFT's
microscopy
myelogram
neurological tests
PV test
serum acid phosphatase test
serum calcium
tissue typing
urine sample
x-rays
x-rays of the back
x-ray of the lumbar spine

7. Investigation Test Results

acid phosphatase abnormal
alkaline phosphatase abnormal
blood count
ESR very high
HLAB27 present
PV very high, elevated
serum acid phosphatase elevated
serum calcium abnormal
tissue typing abnormal
white cell count elevated
x-rays - show degenerative changes

8. Treatments

acupuncture
advice ergonomic back
advice postures
analgesics
anaesthetist
bed rest
exercise
heat treatment
lumbrosacral corset
manipulation
non steroidal anti inflammatory drugs
ostheopath
pain killers
paracetemol
physiotherapy
psychologist
traction
referrals
surgery
ultra sound
The independent assessor was given the following instructions:

Each protocol has 2 parts. The first part is a consultation between the patient and the subject, and the second part is a discussion of the consultation. Note that in the protocol, ES means external supervisor, ST student and PT patient. As an independent assessor, I would like you to look for categories (see the glossaries that contain the encoding vocabulary). Whenever you find a member of one the category, please underline it and put the category number next to it. Also put which phase of the consultation you think it is: h for history, p for physical examination, i for investigations and t treatment.

Example of a category within a sentence
ST: I think that the patient may have a disc problem 1
disc problem is one hypothesis and from the category #1

Example of a category as a sentence
ST: How long have you had the pain? 3
the student asked for the duration of the pain which is a characteristic of the pain, category #3

There is one exception which is category #10 differential diagnosis which contains the hypotheses generated by the subject and which correspond to the subject's diagnosis. For this category, you do not have to check for a match in the glossary, but just underline the hypothesis (or hypotheses) and put the category number next to it. If you find additional data which are not in the glossaries but you think should be there, please let me know. Thank very much for your help.
APPENDIX A6: PROTOCOLS

This appendix contains the protocols of the first 3rd year medical student and of the consultant in orthopaedics.

PROTOCOL OF THE FIRST 3RD YEAR MEDICAL STUDENT

The think aloud session: consultation between the physician and the simulated patient

1 Interviewer  Laurence will be a 42 year old lady complaining of back pain. Shall we take it from there. When it comes to examination just ask me.

2 Student  Hi, my name is N.B., I'm a medical student. Your name is?

3 Patient  My name is Laurence Alpay.

4 Student  How old are you?

5 Patient  I'm 42.

6 Student  Do you work.

7 Patient  No I have been unemployed for two years now.

8 Student  What did you do before that?

9 Patient  I was a secretary.

10 Student  What's the problem. What has brought you into hospital?

11 Patient  Well I have this back pain.

12 Student.  Did it come on suddenly?

13 Patient  Well I woke up with pain.

14 Student  Has it been there ever since?

15 Patient  Yes, its constant.

16 Student  Whereabouts is the pain?

17 Patient  Its about here to here.

18 Student.  And its just on the right side?

19 Patient  Yes.

20 Interviewer  As you are asking questions could you think out aloud as to the sort of questions that are running through your mind. Why are asking these questions?
Can you describe the type of pain to me?

Well its quite a bad pain, its sharp really its there all the time.

Its sharp and there all the time. Does it go anywhere else apart from where you have told me?

No just stays there.

And is it constant or does it come and go?

No it stays.

Have you taken anything to try and relieve it.

I have taken some paracetamol but it did not help. The pain was still there.

Does anything make it worse, any positions?

No its there all the time.

Any idea of what might have caused it?

I don't know

You did not do anything yesterday that might have brought it on.

I was doing some housework but nothing more than usual.

Just if you could mention the sort of things that are running through your mind. Any particular reason for asking those questions?

You are looking for causative factors, so any clues you can get from asking what she did the day before and anything she thinks might have caused it because quite often they wont tell you because they might be too frightened to tell you what caused it if you ask them.

Do you have any clinical diagnosis in mind at this stage.

I haven't a clue.

Apart from your back have you any problems anywhere else. Do you feel ill apart from that? Do you feel well apart from that?

Well not really, I mean I lost my job and things are not too easy at home. I'm not really well, I would not say I am well. I had some waterwork infection in January and I had some trouble about two years ago. You know.

Are you taking any drugs at the moment, any tablets from your doctor.

No nothing.

Have you had this type of problem before?

Well I have, about four years ago I had a disc problem so I went to my GP and was told I had a disc problem.

A disc problem. Is it exactly the same pain as you had then?
Well it seems similar.
Well your not quite sure.
Well it is four years ago. I think its similar.
Did you ever get this type of pain when you had the waterwork infection?
No
Its different from that pain?
Yes.
Did you ever get any pain up to your back?
With the waterwork infection, no.
Right. I am trying to distinguish between renal colic pain and disc pain. Not that I know much about disc pain.
In the past, apart from the waterwork infections which you have had recurrently, have you had any other serious illness?
No, not really.
Have you ever been to hospital before.
Apart from giving birth. No
How many children have you got?
Two.
And they live at home with you do they?
One lives at home with me 17, and the other one is 20 and married and she is away now.
Have you ever had any operations?
No. Nothing.
Just running through the rest of your body just to make sure that you have not forgotten to tell me anything. Ok?
Have you had any shortness of breath, cough, chest pain?
No.
Any palpitations, heard your heart beating in your chest?
No.
Have you been swelling up anywhere?
No.
Have you had any problems with your bowels?
No my bowels are normal.
Any sickness, vomiting.

No.

How's your weight?

A little bit overweight, but not too much.

Your not losing weight?

No

And your waterworks are fine are they?

Yes

No problems going to the toilet?

I forgot to tell you that when I had a waterwork infection it was found that my left kidney was missing.

But you have had no problems with the right?

No.

Apart from that is there anything else you want to tell me?

Well apart from the pain in my back, I dont have any problems really.

That's the main problem?

Well yes.

What do you mean 'well yes', is there something else?

Things are hard at home really.

Because you are unemployed now?

I think so, yes. There is not much money ... with the husband and kids.

Your husband is still at home is he?

He is.

The last time you had this pain were you working?

Yes I was. I was unemployed about two years ago and it happened about four years ago.

Thanks very much. Have we taken the X-rays yet. I dont know anything about orthopaedics. I do not know what to suggest you take. What ever they normally do.

Would you like to examine her for anything in particular?

Well I suppose that we ought to look at the back, legs and see how much movement she has got, how she can move the spine.
99 Interviewer  So when you are looking at the back you notice a bit of spasm on the right side, but otherwise no problem. Anything else?

100 Student  She has no limitation of movement because of her back pain. I mean can I flex her legs and things?

101 Interviewer  You can flex her legs.

102 Student  I don’t know what else to do. She’s got a bit of spasm and that’s it?

103 Interviewer  Yes. So at that stage what would you like to do. What would your plan be and so on?

104 Student  I think at that moment, because of the spasm, can I consult you as my superior or not? Or do you want me to say I would like to consult my superior?

105 Interviewer  I would say yes, you would obviously like to do that. But what I wanted was this to act as a summary of what your present position is. Ok.

106 Student  It seems that you have got this pain in the right side of your back and you do not know what brought it on. And because you have had a disc problem in the past, I think it is worth investigating that further. I will have a chat with my boss and see what he or she thinks. Ok. We will organise the appropriate investigations.

The post interview session: 3rd year medical student

"Student: Hi, my name is N. B., I am a medical student. Your name is?......
Student: What did you do before that?"

107 Student  Well I suppose there I am looking to see whether her past occupation has got anything, any reference. If she had said she had been working as a bricky then that might have done it. Particularly, it would have been relevant to...?

108 Interviewer  Particularly, it would have been relevant to...

109 Student  Her back problem.

110 Interviewer  I am trying to make sure of exactly what you are thinking.

111 Student  I am looking to see whether her previous occupation may have had some relevance on her present condition. So that it might have, if she had been someone who had done lifting or whatever.

112 Interviewer  And what particular problems do you have in mind when you say that?

113 Student  Disc problems.

"Student: How old are you?"

114 Patient  You asked about my age as well.

115 Student  Well, I mean you have to ask age because a lot of things are age related and of course you are more likely to have back problems presumably the longer you get on. I suppose when you get really old you get things like osteoporosis and things which are age
related so its quite important. And also from just looking at the person you can have a fair idea but never be absolutely sure.

"Interviewer: As you are asking questions could you think out aloud as to the sort of questions that are running through your mind. Why are asking these questions?"

116 Interviewer Hold on there, you ask a number of questions about the back pain. Was that for any particular reason?

117 Student I must admit that I have worked out a formula on pain and ask the same questions every time I get a pain. So when you are asking these questions you are not thinking 'why am I asking these questions' until you look back and can get some picture of the character of the pain.

118 Interviewer Yes.

"Student: Have you taken anything to try and relieve it."

119 Student That gives you some idea of the severity of the pain that the paracetamol won't relieve it. Also you get some other things which come in which might state the nature of the cause of the pain if certain things... if like muscular then heat then that might help it, that's the kind of thing I was looking for.

120 Interviewer Right. On the one hand you say that you are working through a formula, running through a set of questions on back pain.

121 Student And then I go out of order.

122 Interviewer No. When you discuss relieving factors you think in terms of whether it would... you think in terms of a particular diagnoses, such as muscular pain. You are doing both at the same time.

123 Student Yes I suppose you are.

"Student: You are looking for causative factors, so any clues you can get from asking what she did the day before and anything she thinks might have caused it ..."

124 Interviewer Causative factors. Do you have anything in particular in mind when you ask about them?

125 Student When I said?

126 Interviewer Asking about 'what you are doing the previous day' for instance?

127 Student Once again, I am thinking about lifting heavy weights because of her disc problem. Basically anything she thinks might have caused it. But she might not be... wouldn't have offered herself but to direct questioning would offer.

128 Interviewer Ok.

"Student: .... Do you feel well apart from that?

129 Interviewer Any particular reason for asking that question?

130 Student Well this was a bit of a shortcut to a systemic enquiry really, which came in the wrong place because I got confused. I was just
trying to see where she had anything else that I could quickly
direct my line of thought to.

131 Interviewer  What did you mean in "the wrong place"?

132 Student  Well as I said I normally go through the drugs and social
history and family, and past medical history, but I think I
came back and did a sort of systemic enquiry anyway.

"Student: Have you had this type of problem before?"

133 Interviewer  You ask first about the drugs, does that fit in with your
routine protocol?

134 Student  Yes, thats still out of order, but its just routine. There are
presenting symptoms, so thats one of the reasons why you ask it.

135 Interviewer  Anything particular in mind there?

136 Student  No.

"Student: A disc problem. Is it exactly the same pain as
you had then?
Patient: Well it seems similar.
Student: Well your not quite sure."

137 Interviewer  Ok the reason for asking that question? Was it part of
routine past medical history?

138 Student  I mean its sort of past medical history, where the patient is
complaining of the same sort of pain. Like I said I'm a bit out of
order. It was intentional to get a past history. Obviously if she
says its the same sort of pain then thats giving you clues once
again to the cause of the pain.

139 Interviewer  I see.

"Student: Right. I am trying to distinguish between renal
colic pain and disc pain. Not that I know much about disc pain."

140 Interviewer  You mention renal colic pain?

141 Student  Renal pain.

142 Interviewer  Renal pain, so not just renal colic?

143 Student  I meant renal pain.

144 Interviewer  I'm sorry. What sort of renal pain would you have in mind?

145 Student  Renal colic is obstructing in the ureters. Renal pain is infection,
descending infection, pyelonephritis. You probably get it with
some chronic renal diseases as well.

"Student: ... have you had any other serious illness?"

146 Student  This is the official PMH (past medical history).

147 Interviewer  So, the previous one was a history of the past complaint?

148 Student  Like I said I got a bit out of order.
When the question as to whether you had anything wrong with your back in the past, that was actually relating to the previous complaint, which is quite a crucial distinction. Whereas this is just a general question.

But I did ask her a general question as well which was a bit...

"Student: How many children have you got?  
Patient: Two.  
Student: And they live at home with you do they?"

Thats kind of like social history there. I was sort of thinking towards the end whether she was depressed at home and whether that was bringing on her symptoms. And I think later on I ask whether she was depressed last time she had the pain.

Well when I asked that general question are you alright generally are you in good health, and she said 'oh well not really' and I kind of probed her a bit about what it was like at home and she said that she was a bit fed up from being at home. Thats the impression I got.

Cardiovascular and respiratory. This is just if incidently you might have had them or may be it was unlikely whether with the symptoms that she's got, but I suppose not, she could have an eroding aortic aneurysm or something like that. You ought to go through things that are connected to her back even if they might not actually be, so you ask systemic questions, and these were respiratory and cardiovascular. Do you want more than that?

No. Then you move on to GI questions and..

Urinary yes.

"Student: Have you had any problems with your bowels?"

Would you ask anything more then. Any gynae questions?

I would normally say I would ask some gynae questions after the urinary ones I suppose really just out of completeness.

"Student: How's your weight?"

Thats just general health type things weight and appetite. So its not just GI questions, even though it fits in there. That can give you quite a lot of other information about other things.

So though you are actually running through a protocol, quite clearly, nevertheless you mark things as being relevant for other reasons.

"Student: Have you had any problems with your bowels?"
An open question?

Yes

For anything particular?

So that the patient has got the option to tell you anything. And also it's a good idea in exams to say what's wrong with them. So that it becomes a habit now.

"Student: The last time you had this pain were you working?"

That's what I said earlier, I was thinking then maybe there was like a depressional psychosis of types and so I was trying to establish whether it was similar to that last time. Just trying to have some idea of her circumstances at home. Though it seems that it was financial she said. And there was also the thing that one kids already left home and the other one was about to flap her wings which I picked up as well.

As a reason for the patient?

As a reason for the patient, I mean she's got back pain, but I think back pain quite often has a psychological basis.

"Student: Well I suppose that we ought to look at the back, legs and see how much movement she has got, how she can move the spine."

The reason for this type of examination?

A bit random really because I am not very clear how you examine a back because I have not done orthopaedics. I was having a stab in the dark about what things you should do.

"Student: It seems that you have got this pain in the right side of your back and you do not know what's brought it on. And because you have had a disc problem in the past, I think it is worth investigating that further. I will have a chat with my boss and see what he or she thinks. OK. We will organise the appropriate investigations"

I suppose I should have given her some pain relief as well.

Something stronger than paracetamol?

Yes.

Nothing you would like to add?

Apart from the pain relief. Thinking of this poor old patient now
PROTOCOL OF THE CONSULTANT IN ORTHOPAEDICS

The think aloud session: consultation between the physician and the simulated patient

1 Interviewer  So as normal a consultation under the circumstances.
2 Consultant  And you want me to think aloud.
3 Interviewer  Yes at the same time. I am merely going to be a neutral presence and prompt you if for some reason you stop thinking aloud. Laurence will be acting as a patient and has been boned up on a particular case. You judge how long you want the interview to go on for and you tell me at the interview the time you would expect. If you want to know any investigation findings then just ask me and I will supply them.
4 Consultant  Hello. Good afternoon. What have you come to see me about.
5 Patient  Good afternoon. Well, I have come to see you because I have a pain in my back which ...
6 Consultant  has been troubling you for a bit.
7 Patient  Yes.
8 Consultant  How long has it been troubling you?
9 Patient  Well, this pain just started this morning. It is really quite painful.
10 Consultant  And you have never had back pain before?
11 Patient  No, I have had back pain before. About four years ago I had a disc problem and was about a week in bed and everything went fine.
12 Consultant  It cleared up?
13 Patient  Yes.
14 Consultant  Ok. At that time, four years ago, when you had your disc problem was your pain confined to your back or did it go anywhere else?
15 Patient  No.
16 Consultant  Just confined to your back?
17 Patient  Yes.
18 Consultant  And who did you actually see, just your general practitioner?
19 Patient  Yes.
20 Consultant  Just your general practitioner. And that settled down on a week's bed rest and you had no further problems.
21 Patient  No.
22 Consultant  Now, this episode of back pain that you had this morning and presumably a bit yesterday, was that exactly the same sort of pain?
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<tbody>
<tr>
<td>23</td>
<td>Patient</td>
<td>Similar, yes.</td>
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<td>24</td>
<td>Consultant</td>
<td>Similar pain. Did you have any pain down your legs at all?</td>
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<td>25</td>
<td>Patient</td>
<td>No. None at all.</td>
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<td>26</td>
<td>Consultant</td>
<td>None at all.</td>
</tr>
<tr>
<td>27</td>
<td>Interviewer</td>
<td>If you could just comment from time to time why you are asking the questions.</td>
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<tr>
<td>28</td>
<td>Consultant</td>
<td>Yes. Ok. The first point to establish in diagnosing back pain really is whether we are dealing with a localised problem in other words whether it is confined to the back, or whether there may be something else, and I will be asking questions in a minute about the rest of you. Secondly, the other main point is whether the pain radiates anywhere. If the pain radiates to the leg it is highly suggestive of a disc problem - a prolapse disc problem - slipped disc, or possibly something else pressing on a nerve, and it is important that if you have had a past history of a slipped disc with true sciatica then the likelihood of you having further episodes is quite high. So, hence my questioning about your past episodes of back pain.</td>
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<tr>
<td>29</td>
<td>Patient</td>
<td>Ok, so apart from this back pain have you been perfectly well?</td>
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<td>30</td>
<td>Consultant</td>
<td>A couple of years ago?</td>
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<td>31</td>
<td>Patient</td>
<td>Yes.</td>
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<td>32</td>
<td>Consultant</td>
<td>Was this because of illness or absence from work?</td>
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<td>33</td>
<td>Patient</td>
<td>No. It was just redundancy. I was a secretary. So things have been quite difficult at home as well.</td>
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<td>34</td>
<td>Consultant</td>
<td>Right. When you had the kidney infection in January did you have any pain in your back?</td>
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<td>35</td>
<td>Patient</td>
<td>Yes.</td>
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<tr>
<td>36</td>
<td>Consultant</td>
<td>Is the pain you have got in your back now, is it a different pain to the pain you had when you had a kidney infection?</td>
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<td>37</td>
<td>Patient</td>
<td>Yes.</td>
</tr>
<tr>
<td>38</td>
<td>Consultant</td>
<td>It is. So you are quite definite that there is no question of you having an infection now in terms of the pain that you've got?</td>
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<td>39</td>
<td>Patient</td>
<td>No, I don't have an infection.</td>
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<td>40</td>
<td>Consultant</td>
<td>Right. So you had a kidney infection. What about your eating habits, have they been troubled at all?</td>
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<td>41</td>
<td>Patient</td>
<td>No.</td>
</tr>
<tr>
<td>42</td>
<td>Consultant</td>
<td>Are your bowels alright? Are you opening your bowels regularly, no problems there at all? No blood nothing like that?</td>
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No. Not at all.

Fine. Your periods are they normal?

Yes, normal - every 28 days.

And you're not pregnant as far as you know?

No.

Fine. The purpose of these questions is to look for pointers to see whether the pain in your back is referred from other organs which can be in your abdomen in other words you can have a gastrointestinal problem which can give you back pain.

So, right this pain that you have got came on over the last 24 hours. Did you do anything yesterday that you think may have set it off?

Well, I was just doing housework, nothing more than usual.

Nothing more than usual. And you have only had this pain once before?

Yes.

And no other time. And the rest of the time your back has been perfectly ok?

Yes.

Alright. Do you find anything that makes the pain better. In other words does lying down make it better?

No. I did not find anything like that.

Is the pain there the whole time?

Yes, its constant.

Constant pain. Does it keep you awake at night or did it keep you awake last night?

Well it woke me up.

It woke you up. It was sufficiently severe?

Yes.

Right. Is the pain fairly well localised, in other words is it in one area of the back or is it just...

Its from here to here on the right side.

On the right side?

Yes.

Does it hurt if you cough or sneeze?

No.
The purpose of that last question really is to see if you have something pressing on the sac of the spinal cord, when you cough and sneeze you increase the pressure in there and if you have something pressing on it such as a tumour or a disc, it gives you a lot more pain.

So we have established that there is nothing that makes this pain better. Is there anything that makes it worse? If you move around does that make it worse?

No, no.

Have you found sitting in a car makes it worse?

No, I didn't notice.

Well, at this stage I think we should proceed to the examination. And the examination takes the form of two parts. First of all there is the general examination of the patient, of you as a patient, which would include a thorough run over your cardiovascular system, respiratory system and gastrointestinal system. I would feel your tummy, take your pulse, blood pressure and so on and so on. Then the second part is more specific to the back, assuming I do not find anything in that to account for your pain that would make me suspicious.

The second thing is to account for your back. Examination really falls into four parts, you look at the patient for a start, you look at the way you are standing and the way that you are walking to see whether there is any limp, tilt or whether your spine is straight and so on. You may have got a scoliosis, curvature of the spine which you have been totally unaware. So the first thing I do is to get you to stand up and look at you, and get you to walk. Then from that it would give me an idea whether we are looking at a mechanical problem of your spine or whether there is something possibly inflammatory. In other words if its a mechanical problem its likely you have a scoliosis, you'll be tilted over to one side, your range of movements of your back would be limited. Then we go through the examination of your back, making you touch your toes, extend your back and go to each side.

The next thing would be to do, would be to feel. So we've looked, we'd feel the parts of the back to see if we can elicit where there is anywhere that is particularly tender that can give us clue as to the organ or organs that might be involved. Then we'd encourage you to move your back as much as you can to find out where the limits of pain are, and that would include also a neurological examination, in the sense of doing a straight leg raising test. We'd put you on the couch, on your back, raise your legs to see if there was any nerve root irritation. Straight leg raising is a good indicator of irritation of the nerve root, as suggested by a disc or possibly a tumour actually sitting in your spine. And then we would go through the reflexes; go through the lower limbs; look at the muscles to see if there was any wasting. What the power of the muscles were like to see if there was any pressure from a nerve causing weakness of muscles, loss of sensation, loss of reflexes. Then if all that was normal and assuming that your general examination was normal, then the next thing to do would be to go into the areas of specific investigation.

Before that if I just mention a couple of factors on examination. You find no localised tenderness on the spine. You find some generalised tenderness from the spine out towards the - over the
right lumbar region. You do find some signs of spasm on the right side. The neurological signs are absent. There are no abnormal neurological signs. Straight leg raising was 800 on the affected side and 900 on the other side.

Which is probably not statistically significant. Right there is no localised tenderness. And we assume from the general examination that abdomen and pelvic organs are normal? Right.

The next thing to do would be to take an X-ray. We will take an X-ray of your pelvis and your chest. And by the way perhaps I should have added that in the course of examining your back, the other thing that one always looks at is hips. In other words when I do my straight leg raising test, the way that I do it is to bend the knee first, lift the leg up, waggle the hip to elicit whether there is pain coming from the hip. This can be very confusing. The patient has complained of pain in the hip and they have got back pathology and vica versa and so it might ... I should have mention it, but you do it automatically, but one must obviously rule out that sort of a problem. So I'd take an X-ray of your pelvis and of your hips, and of the lower part of your lumbosacral spine, so in other words it would go from about there downwards. So we would look at these and the standard views are three views, and we would look at these to see if there was any change in the bony architecture, whether the soft tissue shadows on the X-rays have been obliterated indicating possibly something bad, obliterating pathology there. If we were happy that everything was plum normal then the next thing to do would be a full blood, ESR and a CRP, which is an indicator of inflammation/infection and I would do a bone biochemistry as well.

That also comes back normal.

Ok. In view of the fact that you have had a urinary tract infection in the past I think we ought to rule that out. In other words I would take a specimen of your urine to check that there is no occult infection there and if you have not had a recent IVP then probably an ultrasound of the kidney followed by an IVP would be what I would go for, and I would talk to the radiologist about that. But we would want to make absolutely certain that you had not got a stone or anything like that, partial obstruction, which can of course give you quite nasty backache. If that was normal then we are really down to the gynaecological bits and pieces. If I felt there was any indication at all for a gynaecological opinion then I would ask for that, in other words you could have a retroverted uterus, fibroids or something like that, which I as an orthopaedic surgeon would be pushed to detect. I think I would ask for an expert opinion on that.

If effectively we had cleared up all the reasons other than orthopaedic for your back pain, then the next investigation I think should be a technesium bone scan. Now a technesium bone scan gives an indication of increased blood flow to a particular area of bone. There is an increased blood flow when there is inflammation, infection or tumour. So that this may give us an idea whether there was sacroiliac joint inflammation. It is unlikely that the ESR and CRP are normal, but nonetheless it could be there. Acute on chronic infection, again we come back to tumour, osteoid osteomas fairly classical always being missed in back pain, especially in young patients. The only thing that really does pick them up is a bone scan. Now if the bone scan came back hot in any particular area, that would indicate to me that there was something going on in that area, we wouldn't be able to tell
you what it was. So the next investigation after that would probably be a CT scan or possibly an MRI scan of that area. Now that would give us a better idea of the sort of pathology that we are dealing with.

79 Interviewer I think we are really at the limits of thinking perhaps after a particular consultation. Unless there was anything else you would like to ask the patient.

80 Consultant I don't think so. Obviously I have just sort of rattled through it. This would not happen on day one. So we'd need to go through this. But that was my thinking.

81 Interviewer Could we just outline what you would do on day one.

82 Consultant Yes. On day one it would be taking of the history, general examination and a specific examination of the patient. The bloods would be taken for a full blood count and the bone biochemistry, uric acid, rheumatoid as appropriate. And X-rays would be taken and I would view the X-rays with the patient after they come back from X-ray. I would not obviously have the results of the blood test so we would have to wait for that. So assuming that the X-rays were within normal limits I would await the results of the blood tests. The only modification I would add to that, depending obviously on the patients pain, is if the patient is in dire agony and really can't move and has severe problems then one would have to think about hospitalising him or her.

83 Interviewer The patient has walked in.

84 Consultant Ok, then I would say that there are no clear indications as to what is causing this and we need to follow this up with investigations. I get the blood test within a couple of days, and the next step if they were normal would be to proceed along the lines that I have outlined.

The post interview session: Consultant

"...Laurence will be acting as a patient and has been boned up on a particular case..."

85 Interviewer Laurence was actually meant to be a 42 year old lady. I realised that about half way through.

86 Patient Yes, because he said a young patient and I realised..

87 Interviewer Would it have affected your thinking in anyway if you had known that Laurence was 42 rather than..

88 Consultant No, because the things that you are thinking about at that age are obviously gynaecological problems, ectopic pregnancies present at that age, simply because ladies that age are not expected to get pregnant but they do. Tumours breast tumours can present as secondaries in the spine at 42, but that would have been covered in my general examination of lumps and bumps and at 42 thats a classic age for degenerative changes happening in the back. Yes, the answer is it would influence... if you take somebody at 20 and are going to rule out the common causes of back pain. In a 20 year old there are disc problems but when you hit your 40s and 50s the commonest is degenerative changes, so when I say disc problems I say prolapsed intervertebral disc problems. 40s and 50s
you are talking about degenerative changes that involve sagging discs not actually prolapsed ones, ones you would call backache rather than sciatica and degenerative - ah joint problems. And in the older group 60s and 70s then clearly tumour, secondaries come top of the list.

"Consultant: How long has it been troubling you?"

89 Interviewer Reason for asking the length of time?
90 Consultant I was just trying to work out why I was asking that question. Ok, if it had been troubling you for a long time then we would be dealing with a chronic problem. In other words one that has probably come on slowly and built up. If it has been troubling you for a short time, as you said it came on yesterday, then the chances are, well definitely that we are dealing with an acute problem and there may be a specific cause as to why that happened. In other words the reason for my asking that was the followup to a later question, precedes a later question 'do you remember doing anything that could have caused that pain' and you could have said 'ok yes, I went and shifted 10 tons of sand or dug my acre of garden' and those two points will tie together. If you had said to me that it had been on for about three months or six months gradually increasing then the chances of trauma causing it, in other words one specific episode causing it are very slight. So that was the reason for asking how long it had been.

"Consultant: Ok. At that time, four years ago, when you had your disc problem was your pain confined to your back or did it go nowhere else?"

91 Interviewer Ok. Reason for asking that?
92 Consultant Its important to work out whether the pain that you have now is similar to the one you had four years ago. If you had had pain radiating from your back into your legs then it would have been suspicious of a disc problem if you had had a disc problem four years ago then you would have had a reasonable chance that the problem that you now have is due to the same cause.

93 Interviewer At this point in the conversation where you know that Laurence has had an episode of PID in the past, that she woke with back pain this morning which does not radiate, what are your thoughts as to whats going on?

94 Consultant Assuming that you had had a disc problem in the past?
95 Interviewer To Patient, did you not just mention that.
96 Patient Yes, I did.
97 Consultant It leads on to one of my questions later on, what a GP or you may call a disc problem, may not equate to what I am prepared to call a disc problem and that was the point of my question 'who did you see?' You saw a GP. With the greatest respect to GPs and indeed to orthopaedic surgeons, we all get the diagnoses wrong on occasions. There is a difference to having a disc problem where you may have ruptured the disc but not actually squirted any material out to cause sciatica. You could argue that every person that has back pain has some sort of a disc problem, that may well be correct, but the point that I am interested in because of the implications for surgery are whether there is a sequestration of the disc, in other words it has come out and its pressing on a nerve
Do you have any particular diagnosis, or diagnoses in mind at this stage or?

Consultant: Just your general practitioner. And that settled down on a week's bed rest and you had no further problems.

Do you want me to explain that? Right, mostly.. 80% or 85% of disc problems will settle on bed rest. You normally give a patient two to three weeks in bed for a good going disc with sciatica and if they have not got better after that then they come for further investigations. So the point is that if it clears up fairly smartly, the chances of it being a prolapsed disc, bearing in mind the accuracy of the diagnosis that we are not particularly certain about, the chances of it being a prolapsed disc are not too high. You did not have any nagging problems, or problems that went on for six months before. you've never had a problem back, and patients come and tell you that once they have had one period of back pain they have a problem back for the rest of their life. It was going through my mind at that stage that she may or may not have had a disc problem. We may be dealing with something new.

Consultant: Ok, so apart from this back pain have you been perfectly well?

The reasons that we ask these questions is that the back can be the site of referred pain and one wants to establish fairly early on in the interview whether we are dealing with another organ system, in other words not a musculoskeletal problem. For example, a gastro-intestinal problem such as pancreatitis, for example can produce quite severe and disabling back pain. Gynaecological problems in ladies is a common cause of back, for example retroverted uterus, tumours, pelvic inflammatory disease, ectopic pregnancy and so on. So general questions about your health will be referring to that, especially as you had had a problem with the kidneys in the past. That would be the first thing to try and exclude without investigations, just by talking to you hat this has nothing to do with your present episode of back pain.

Consultant: Was this because of illness or absence from work?
Patient. No. It was just redundancy. I was a secretary. So things have been quite difficult at home as well.
It's important, in the history again you said you had lost your job. Now if you had lost your job because of repeated episodes of illness, then I will actually say this is due to your back pain because some patients are reticent about telling you about their history they give you snippets. So you have to hammer them quite hard to get it out of them what had happened. And if you had actually said to me then 'ho, goodness I lost my job because I was away two days a week with my back niggling and I thought it was my period pains or I thought it was this or that', then this opens a whole new avenue for investigation. You lost it because you were made redundant is not relevant to the medical history.

"Consultant: Right. When you had the kidney infection in January did you have any pain in your back?"

Absent kidney mentioned with a couple of UTIs?

Yes, clearly you need to find out we are not dealing with kidney infection, kidney stone or that kind of pathology in a broader sense. Sorry, which kidney did you say you had missing?

The left one.

And you have pain on the right side?

Yes.

Well, I think that would be yes. That would come fairly early on in my ruling out. It's a diagnosis by exclusion. It does not sort of leap out and hit you the diagnosis. In terms of a musculo-skeletal problem, then you have to do it by exclusion. The first thing to start with is where you have had problems such as your renal tract.

"Consultant. It is. So you are quite definite that there is no question of you having an infection now in terms of the pain that you've got?"

At this point?

Well you are trying to find out whether the pains are similar or dissimilar. You have been quite categoric that the two pains are dissimilar so the kidney problem recedes in terms of causation of the present back problem.

So working diagnoses at this stage?

It's still going to work as a mechanical problem I think from everything you have said to me so far. It's likely to remain a mechanical problem. Mechanical in the broad sense of the word which means that the spinal unit which consists of the two vertebral bodies, the disc in between and the fourchette (? spelling) joints in the back. That is the sort of area we are looking at.

"Consultant: Right. So you had a kidney infection. What about your eating habits, have they been troubled at all?"

Eating habits?
Again, ulcer, pancreatitis, gall bladder disease, they are all gastrointestinal problems that can give rise to back pain. Unlikely at the low level but nonetheless present. A lot of indigestion, or you may have got some sort of obstruction in your gut.

"Consultant: Are your bowels alright? ...."

Anything specific about bowels?

Carcinoma of the rectum can often present with back pain either from local infiltration or from secondaries. So it is important to exclude the commoner causes of tumour.

"Consultant: Nothing more than usual. And you have only had this pain once before?"

Frequency?

One wants to look at that, as I said before most patients are reticent about saying how many times they have had back pain and furthermore they forget, and I think it is important to keep asking them as they may suddenly say 'oh gosh'. It is an association of ideas, so I keep repeating the questions.

"Consultant: Alright. Do you find anything that makes the pain better. In other words does lying down make it better?"

If it's a mechanical type of pain or a disc problem very often bedrest will relieve the pain and conversely it is true that if it is a mechanical type of problem and you are getting up and doing a particularly arduous type of job, bending picking things up, then it makes it worse. Those are the sorts of things.

"Consultant: Constant pain. Does it keep you awake at night or did it keep you awake last night?"

The significance of that is that pain wakes people up at night if it is severe. If its sufficiently bad to wake you up then it gives us an objective gradation of the level of pain. Pain is an extremely difficult thing to produce a level of and so some people have a very high threshold. Pain that wakes you at night is significant.

Perhaps I ought to mention that in this case the patient actually woke up with the pain. There is a difference between the patient being woken up by the pain and waking up with the pain and its the second of these two.

Woke up and found that they had pain?

Yes.

Ok

At the point of coming to the examination

Before we hit that, what is your working diagnoses at this stage?

Well I must admit that if nothing makes it better and nothing makes it worse one is looking for, still mechanical is more likely, but nonetheless at the age group 42 one would be very concerned
about an inflammatory cause. Possibly at 42 you would be too old for an osteo-osteoma but one would think about tumour as well. Anything that gives you a continuous boring pain. One really has to rule out tumour especially when at night.

"Consultant: ....which would include a thorough ...over your cardiovascular system, respiratory system and gastrointestinal system. I would feel your tummy, take your pulse, blood pressure and so on and so on."

127 Interviewer How thorough would you be on these different systems before examination of the back?

128 Consultant Well I think that on the history that I have got, I would be quite thorough because it does not sound to me that it is a clear cut orthopaedic problem. What I have not mentioned are the other things that you feel for, such as lumps and bumps in the breasts, any lymphadenopathy. If one came across any generalised pathology then obviously you are going to home in on that. But I am not sure I can be more specific than that.

129 Interviewer Right. So would you for instance be examining the lungs?

130 Consultant Yes, my examination of the lungs is not obviously the standard of a chest physician, but I would want to listen and while I am doing it, I might ask 'are you a heavy smoker'.

131 Interviewer Right.

132 Consultant If that were the case then into my investigations at 42 I would probably want to do a chest X-ray if there were indications for doing it.

"Consultant: Then if all that was normal and assuming that your general examination was normal, then the next thing to do would be to go into the areas of specific investigation."

133 Interviewer Just before that, diagnoses at this stage, along with the examination results that I have mentioned?

134 Consultant So we have found effectively nothing in terms of general examination and slightly restricted range of movement on the right?

135 Interviewer Yes, on the right side, and some tenderness from the spine over towards the loin region. And straight leg raising of 800.

136 Consultant I suppose one of the questions I should have asked straight away was what nationality is this patient?

137 Interviewer Caucasian.

138 Consultant Right. Well the sort of things I would be looking at are first of all infection in the orthopaedic world anyway and secondly tumour.

139 Interviewer Why do you ask about nationality?

140 Consultant Because I have worked in the Far East and Africa and Napal and places like that and out there top of the list of every single diagnosis is tuberculosis and I am still highly suspicious. In fact we have just diagnosed a caucasian with TB of her spine, which I am sure would not have been picked out unless somebody had had a bit of experience. There is an increasing number of people
in Britain who do have TB of their spine and therefore that is a classical presentation.

So working diagnosis?

So working diagnosis would be at the moment an inflammatory, infective disorder though tumour would not be far, those are my three sort of things, and I would want to exclude those and that would really take me on to the next thing of specific investigations.

Moving on to investigations.

Ok, the investigations come in two parts first of all the radiological investigations. And these would be done there and then and I would review the x-rays with the patient - in other words it would form part of the first consultation. The areas to be X-rayed would obviously be the pelvis and the lumbosacral spine. If there had been either any indication from the history or examination that the chest should be X-rayed then I would do it. If the patient was middle aged ie 50 or above then I would actually get a chest X-ray and anybody who was over 35 and a heavy smoker I would get a chest X-ray, and the reason for that is that lung tumours are relatively common in smokers and can present as silent secondaries. So that would be the reasoning for taking X-rays. The bloods would be taken for a full blood count and ESR. The full blood count would tell me that healthiness if you like of the blood picture, whether the patient was anaemic due to a chronic blood problem, or whether there were indications for further investigation in that field, and I am thinking here along the lines of tumours of basically blood tissue, leukaemias etc. The ESR is a non-specific investigation which tells me whether there is likely to be inflammation or infection, as is the CRP, they are useful generalised indicators to whether we are winning or losing. In other words you take a series or of ESR or series of CRPs during treatment.

I would do a bone biochemistry as it would be important to know whether we are dealing with a possible upset of the bone biochemistry. Calcium and phosphate, alkaline phosphatase is a sensitive indicator of bone activity. Uric acid to make absolutely certain we are not dealing with gout and rheumatoid factor as well, unlikely but we should rule it out. Those would be my first general investigations. What we are trying to reduce is the area in which we are looking. We are excluding diagnoses as we go along until we get down to the nitty gritty at the bottom.
APPENDIX A7: PLANS OF THE SUBJECTS

Ten physicians took part in an empirical study. Half of the physicians' protocols were used to build a model of changes of strategies over time. This appendix contains plans constructed from the protocols of these subjects. In particular, it contains plans of:

First 3rd year student
4th year student
First 5th year student
House officer
General Practitioner

Each plan contains the physician's goals, their strategies and interactions of strategies associated with them.
GLOBAL PLAN OF THE 3RD YEAR STUDENT #1
(page 1)

check_back_pain
check_past_medical_history
check_social_history
check_medicines_taken
check_other_problems
check_age
check_occupation

check_back_pain_history

check_characteristics_pain
check_prevous_back_pain

check_duration_pain
check_severity_pain
check_epidemic
check_past_medical_history
check_previous_back_pain

check_characteristics_pain

check_waterwork_infections
check_past_waterwork_infections
check_back_pain

338
GLOBAL PLAN OF THE 5TH YEAR STUDENT #1

check, diagnosis, patient

check, history

check, physical examination

check, neurological examination

check, investigations

check, samples

check, back pain history

check, characterisation, pain

check, previous back pain

check, characteristic, pain

check, duration, pain

check, radiation, pain

check, relieving factors

check, aggravating factors

check, sudden onset

check, gradual onset

HGN

HGN

PREF

PREF

check, previous back pain

check, similar pain

check, work-related infections, problems

check, current work-related infections

check, past work-related infections

PREF

PREF

HGN

SPIC

CONF

ELIM
APPENDIX A8: THE GLOBAL PLAN

Appendix 7 contains the plans of the five physicians' protocols that were used to build a model of strategies over time. A global plan that combines the goals of the five plans was constructed and is found in this appendix. The global plan will be used as a plan of reference in the testing of the system using the other half of the protocols (reported in chapter 10).
APPENDIX A9: EXAMPLES OF ENCODING THE STRATEGIES

This appendix contains examples of encoding the reasoning strategies from actual protocols. Underlined utterances are utterances which have been coded.

• Generalisation:
The expert asked the patient about her eating habits during the consultation with the patient. When probed during the post interview session about this question he made three generalisations.

Protocol
Interviewer: eating habits?

Consultant: Ulcer, pancreatitis, gall bladder diseases.
they are all gastrointestinal problems

Encoding
GEN(hypothesis specific: ulcer
hypothesis general: gastrointestinal problem
evidence: appetite habits
goal: check appetite habits
phase: history)

There are two other generalisations: pancreatitis to gastrointestinal problem and gall bladder disease to gastrointestinal problem.

• Specialisation:
The first 3rd year student mentioned renal pain and was asked about it in the post interview session. She made two specialisations from infection to descending infection and from infection to pyelonephritis.
Protocol

First 3rd year student: Renal pain is infection, descending infection, pyelonephritis

Encoding

SPEC(hypothesis general: infection, hypothesis specific: descending infection, goal: check kind of pain, phase: history)
 SPEC(hypothesis general: infection, hypothesis specific: pyelonephritis, goal: kind of pain, phase: history)

**Confirmation:**

The GP-T used a number of pieces of evidence such as the location of the pain, and the patient's past history to explain the patient case and tries to confirm disc problem.

Protocol

GP-T: due to the site of the pain and since it has come on quite suddenly and in view of the past history, I thought of possible disc problem playing again.

Encoding

CONF(hypothesis: disc problem, evidence: [location of the pain, onset of the pain and past history] in the differential: disc problem, goal: check back pain history, phase: history)

**Elimination:**

The house officer was probed about asking the patient if she had injured her back in the past and she made two eliminations.
Interviewer: injured back?
HO: to rule out pyelonephritis and inflammatory condition

Encoding
ELIM(hypothesis: pyelonephritis evidence: history of injured back out of the differential: pyelonephritis goal: check accident back phase: history)
ELIM(hypothesis: inflammatory condition evidence: history of injured back out of the differential: inflammatory cond. goal: check accident back phase: history)

• Problem Refinement:
The first 3rd year student refined the pain by asking the patient which medications she took to relieve the pain.

Protocol
Replay of a question in the think aloud session
First 3rd year student: Have you taken anything to try and relieve the pain?
Patient: I have taken paracetamol but it did not help. The pain was still there

Student’s explanation in the post interview session
First 3rd year student: That gives you some idea of the severity of the pain

Encoding
PREF(observation: no relieving factors observation refined to: refine the severity of the pain goal: check relieving factors phase: history)

• Hypothesis generation:
The first 5th year student asked about radiation of the pain because of the possibility of sciatica.
Protocol

Replay of a question in the think aloud session
First 5th year student: and is the pain just in your back or do you get any in the leg at all?

Patient: No, just in the back, just in the area I showed you.

Student's explanation in the post interview session
First 5th year student: I was asking about sciatica

Encoding
HGN(observation: no radiation of the pain hypothesis: sciatica goal: check radiation of the pain phase: history)

• Anatomical based strategy
The 4th year student asked the patient about aggravating or relieving factors, and used some anatomical information to explain what can be the problem.

Protocol

Replay of a question in the think aloud session
4th year student: Has it [the pain] becomes worst?

Patient: It stays the same

4th year student: Well, when you move about does it get worse? is it better for you to sit or to lie down? what do you think?

Patient: It's the same

Student's explanation in the post interview session
4th year student: the disc is going into the hole of the spine.
Encoding

ANAT(observation: no aggravating or relieving factors
anatomical information: disc going into the hole of the spine
goal: check aggravating relieving factors
phase: history
APPENDIX B1: THE PHYSICIANS' LIST OF GOALS

This appendix contains the list of goals of each of the ten physicians interviewed in the study. The goals derived from the protocols that were used to build up the system are first given, followed by the goals derived from the protocols that were used to test the system.

GOALS DERIVED FROM PROTOCOLS USED TO DESIGN THE SYSTEM

/* DEFAULT_GOAL of the first 3rd year medical student */
default_goal(check_diagnose_patient).
default_goal(check_history).
default_goal(check_back_pain_history).
default_goal(check_characteristics_pain).
default_goal(check_duration_pain).
default_goal(check_severity_pain).
default_goal(check_episodic_continue_pain).
default_goal(check_episodic_continue_pain_more).
default_goal(check_location_pain).
default_goal(check_location_pain_more).
default_goal(check_radiation_pain).
default_goal(check_relieving_factors).
default_goal(check_relieving_factors_more).
default_goal(check_previous_back_pain).
default_goal(check_similar_pain).
default_goal(check_kind_of_pain).
default_goal(check_waterwork_infections_problems).
default_goal(check_past_waterwork_infection).
default_goal(check_pain_with_waterwork_infection).
default_goal(check_back_pain_with_waterwork_infection).
default_goal(check_past_medical_history).
default_goal(check_general_health).
default_goal(check_weight).
default_goal(check_past_operations).
default_goal(check_past_illnesses).
default_goal(check_cardio_respiratory).
default_goal(check_gyne).
default_goal(check_social_history).
default_goal(check_situation_home).
default_goal(check_nb_children).
default_goal(check_details_children).
default_goal(check_medicines_taken).
default_goal(check_current_medicines).
default_goal(check_other_problems).
default_goal(check_age).
default_goal(check_occupation).
default_goal(check_recent_occupation).
default_goal(check_physical_examination).
default_goal(check_examination_back).
default_goal(check_posture).
default_goal(check_flexion).
default_goal(check_flexion_legs).

/* DEFAULT_GOAL of the 4th year medical student */
default_goal_4th(check_diagnose_patient).
default_goal_4th(check_history).
default_goal_4th(check_back_pain_history).
default_goal_4th(check_characteristics_pain).
default_goal_4th(check_location_pain).
default_goal_4th(check_location_pain_more).
default_goal_4th(check_radiation_pain).
default_goal_4th(check_radiation_previous_pain).
default_goal_4th(check_aggravating_relieving_factors).
default_goal_4th(check_movements_legs).
default_goal_4th(check_previous_back_pain).
default_goal_4th(check_similar_pain).
default_goal_4th(check_waterwork_infections_problems).
default_goal_4th(check_past_waterwork_infections).
default_goal_4th(check_pain_with_waterwork_infection).
default_goal_4th(check_treatment_previous_back_pain).
default_goal_4th(check_past_medical_history).
default_goal_4th(check_past_illnesses).
default_goal_4th(check_kidney_problems).
default_goal_4th(check_bowel).
default_goal_4th(check_urine).
default_goal_4th(check_occupation).
default_goal_4th(check_physical_examination).
default_goal_4th(check_examination_back).
default_goal_4th(check_palpation).
default_goal_4th(check_neurological_examination).
default_goal_4th(check_reflexes).
default_goal_4th(check_reflexes_lower_limbs).
default_goal_4th(check_investigations).
default_goal_4th(check_xrays).
default_goal_4th(check_back_xrays).
default_goal_4th(check_lower_back_xrays).

/* DEFAULT_GOAL of the first 5th year medical student */
default_goal_5th1(check_diagnose_patient).
default_goal_5th1(check_history).
default_goal_5th1(check_back_pain_history).
default_goal_5th1(check_characteristics_pain).
default_goal_5th1(check_duration_pain).
default_goal_5th1(check_sudden_onset).
default_goal_5th1(check_gradual_onset).
default_goal_5th1(check_radiation_pain).
default_goal_5th1(check_relieving_factors).
default_goal_5th1(check_aggravating_factors).
default_goal_5th1(check_previous_back_pain).
default_goal_5th1(check_similar_pain).
default_goal_5th1(check_waterwork_infections_problems).
default_goal_5th1(check_current_waterwork_infections).
default_goal_5th1(check_past_waterwork_infections).
default_goal_5th1(check_past_medical_history).
default_goal_5th1(check_kidney_problems).
default_goal_5th1(check_physical_examination).
default_goal_5th1(check_examination_back).
default_goal_5th1(check_palpation).
default_goal_5th1(check_flexion).
default_goal_5th1(check_neurological_examination).
default_goal_5th1(check_slr).
default_goal_5th1(check_investigations).
default_goal_5th1(check_xrays).
default_goal_5th1(check_back_xrays).
default_goal_5th1(check_abdominal_xrays).
default_goal_5th1(check_samples).
default_goal_5th1(check_urine_sample).

/* DEFAULT_GOAL of the house officer */
default_goal_ho(check_diagnose_patient).
default_goal_ho(check_history).
default_goal_ho(check_back_pain_history).
default_goal_ho(check_characteristics_pain).
default_goal_ho(check_duration_pain).
default_goal_ho(check_severity_pain).
default_goal_ho(check_episodic_continue_pain).
default_goal_ho(check_location_pain).
default_goal_ho(check_radiation_pain).
default_goal_ho(check_aggravating_relieving_factors).
default_goal_ho(check_previous_back_pain).
default_goal_ho(check_similar_pain).
default_goal_ho(check_accident_back).
default_goal_ho(check_waterwork_infections_problems).
default_goal_ho(check_past_medical_history).
default_goal_ho(check_general_health).
default_goal_ho(check_feeling_hot_sweaty).
default_goal_ho(check_feeling_fit).
default_goal_ho(check_appetite_habits).
default_goal_ho(check_quantity_food).
default_goal_ho(check_sleeping_habits).
default_goal_ho(check_time_sleep).
default_goal_ho(check_smoking).
default_goal_ho(check_drinking).
default_goal_ho(check_past_operations).
default_goal_ho(check_past_operations_back).
default_goal_ho(check_past_illnesses).
default_goal_ho(check_allergies).
default_goal_ho(check_social_history).
default_goal_ho(check_situation_home).
default_goal_ho(check_family_members).
default_goal_ho(check_medicines_taken).
default_goal_ho(check_current_medicines).
default_goal_ho(check_results_current_medicines).
default_goal_ho(check_physical_examination).
default_goal_ho(check_examination_back).
default_goal_ho(check_palpation).
default_goal_ho(check_palpation_vertebrae).
default_goal_ho(check_palpation_muscle).
default_goal_ho(check_posture).
default_goal_ho(check_flexion).
default_goal_ho(check_touch_toes).
default_goal_ho(check_bending).
default_goal_ho(check_rotation).
default_goal_ho(check_neurological_examination).
default_goal_ho(check_reflexes).
default_goal_ho(check_reflexes_lower_limbs).
default_goal_ho(check_slr).
default_goal_ho(check_investigations).
default_goal_ho(check_xrays).
default_goal_ho(check_xrays_back).

/* DEFAULT_GOAL of the GP */
default_goal_gp(check_diagnose_patient).
default_goal_gp(check_history).
default_goal_gp(check_back_pain_history).
default_goal_gp(check_characteristics_pain).
default_goal_gp(check_duration_pain).
default_goal_gp(check_severity_pain).
default_goal_gp(check_location_pain).
default_goal_gp(check_location_previous_pain).
default_goal_gp(check_radiation_pain).
default_goal_gp(check_radiation_previous_pain).
default_goal_gp(check_aggravating_relieving_factors).
default_goal_gp(check_previous_back_pain).
default_goal_gp(check_similar_pain).
default_goal_gp(check_work_water_infection_problems).
default_goal_gp(check_treatment_previous_back_pain).
default_goal_gp(check_age).
default_goal_gp(check_occupation).
default_goal_gp(check_recent_occupation).
default_goal_gp(check_past_medical_history).
default_goal_gp(check_general_health).
default_goal_gp(check_appetite_habits).
default_goal_gp(check_weight).
default_goal_gp(check_bowel).
default_goal_gp(check_physical_examination).
default_goal_gp(check_examination_back).
default_goal_gp(check_palpation).
default_goal_gp(check_palpation_muscle).
default_goal_gp(check_posture).
default_goal_gp(check_reflexes).
default_goal_gp(check_slr).
default_goal_gp(check_investigations).
default_goal_gp(check_samples).
default_goal_gp(check_urine_sample).

GOALS DERIVED FROM PROTOCOLS USED TO TEST THE SYSTEM

/* DEFAULT_GOAL of the second 3rd year medical student */
default_goal_eval_3rd(check_diagnose_patient).
default_goal_eval_3rd(check_history).
default_goal_eval_3rd(check_back_pain_history).
default_goal_eval_3rd(check_characteristics_pain).
default_goal_eval_3rd(check_duration_pain).
default_goal_eval_3rd(check_severity_pain).
default_goal_eval_3rd(check_severity_pain_more).
default_goal_eval_3rd(check_episodic_continue_pain).
default_goal_eval_3rd(check_radiation_pain).
default_goal_eval_3rd(check_aggravating_factors).
default_goal_eval_3rd(check_aggravating_factors_more).
default_goal_eval_3rd(check_previous_back_pain).
default_goal_eval_3rd(check_similar_pain).
default_goal_eval_3rd(check_treatment_previous_back_pain).
default_goal_eval_3rd(check_past_medical_history).
default_goal_eval_3rd(check_past_medical_history_more).
default_goal_eval_3rd(check_sleeping_habits).
default_goal_eval_3rd(check_time_sleep).
default_goal_eval_3rd(check_gyne).
default_goal_eval_3rd(check_gyne_more).
default_goal_eval_3rd(check_social_history).
default_goal_eval_3rd(check_backpain_problem_in_family).
default_goal_eval_3rd(check_number_children).
default_goal_eval_3rd(check_details_children).
default_goal_eval_3rd(check_accommodation).
default_goal_eval_3rd(check_medicines_taken).
default_goal_eval_3rd(check_recent_occupation).
default_goal_eval_3rd(check_physical_examination).
default_goal_eval_3rd(check_examination_back).
default_goal_eval_3rd(check_palpation).
default_goal_eval_3rd(check_posture).
default_goal_eval_3rd(check_posture_more).
default_goal_eval_3rd(check_flexion).
default_goal_eval_3rd(check_touch_toes).
default_goal_eval_3rd(check_rotation).
default_goal_eval_3rd(check_neurological_examination).
default_goal_eval_3rd(check_slr).
default_goal_eval_3rd(check_investigations).
default_goal_eval_3rd(check_xrays).
default_goal_eval_3rd(check_xrays_more).
default_goal_eval_3rd(check_xrays_once_more).
default_goal_eval_3rd(check_samples).
default_goal_eval_3rd(check_blood_samples).

/* DEFAULT_GOAL of the second 5th year medical student */
default_goal_eval_5th(check_diagnose_patient).
default_goal_eval_5th(check_history).
default_goal_eval_5th(check_back_pain_history).
default_goal_eval_5th(check_characteristics_pain).
default_goal_eval_5th(check_duration_pain).
default_goal_eval_5th(check_gradual_onset).
default_goal_eval_5th(check_sudden_onset).
default_goal_eval_5th(check_severity_pain).
default_goal_eval_5th(check_location_pain).
default_goal_eval_5th(check_radiation_pain).
default_goal_eval_5th(check_aggravating_factors).
default_goal_eval_5th(check_location_pain).
default_goal_eval_5th(check_aggravating_factors).
default_goal_eval_5th(check_previous_back_pain).
default_goal_eval_5th(check_similar_pain).
default_goal_eval_5th(check_waterwork_infections_problems).
default_goal_eval_5th(check_current_waterwork_infections).
default_goal_eval_5th(check_past_waterwork_infections).
default_goal_eval_5th(check_past_medical_history).
default_goal_eval_5th(check_past_illnesses).
default_goal_eval_5th(check_kidneys_problems).
default_goal_eval_5th(check_check_physical_examination).
default_goal_eval_5th(check_palpation).
default_goal_eval_5th(check_palpation_vertebrae).
default_goal_eval_5th(check_maxion_passive).
default_goal_eval_5th(check_maxion_legs_passive).
default_goal_eval_5th(check_bending_back_passive).
default_goal_eval_5th(check_rotation_passive).
default_goal_eval_5th(check_maxion_active).
default_goal_eval_5th(check_maxion_legs_active).
default_goal_eval_5th(check_bending_back_active).
default_goal_eval_5th(check_rotation_active).
default_goal_eval_5th(check_touch_toes).
default_goal_eval_5th(check_abdominal_examination).
default_goal_eval_5th(check_palpation_kidneys).
default_goal_eval_5th(check_breast_chest_examination).
default_goal_eval_5th(check_investigations).
default_goal_eval_5th(check_xrays).
default_goal_eval_5th(check_back_xrays).
default_goal_eval_5th(check_abdominal_xrays).
default_goal_eval_5th(check_chest_xrays).
default_goal_eval_5th(check_samples).
default_goal_eval_5th(check_urine_sample).
/* DEFAULT_GOAL of the senior house officer */
default_goal_eval_sho(check_diagnose_patient).
default_goal_eval_sho(check_history).
default_goal_eval_sho(check_back_pain_history).
default_goal_eval_sho(check_characteristics_pain).
default_goal_eval_sho(check_duration_pain).
default_goal_eval_sho(check_severity_pain).
default_goal_eval_sho(check_location_pain).
default_goal_eval_sho(check_radiation_pain).
default_goal_eval_sho(check_relieving_factors).
default_goal_eval_sho(check_aggravating_factors).
default_goal_eval_sho(check_previous_back_pain).
default_goal_eval_sho(check_accident_back).
default_goal_eval_sho(check_waterwork_infections_problems).
default_goal_eval_sho(check_current_waterwork_infections).
default_goal_eval_sho(check_past_waterwork_infections).
default_goal_eval_sho(check_treatment_previous_back_pain).
default_goal_eval_sho(check_treatment_previous_back_pain_more).
default_goal_eval_sho(check_past_medical_history).
default_goal_eval_sho(check_past_illnesses).
default_goal_eval_sho(check_kidneys_problems).
default_goal_eval_sho(check_age).
default_goal_eval_sho(check_occupation).
default_goal_eval_sho(check_recent_occupation).
default_goal_eval_sho(check_physical_examination).
default_goal_eval_sho(check_examination_back).
default_goal_eval_sho(check_palpation).
default_goal_eval_sho(check_palpation_muscle).
default_goal_eval_sho(check_palpation_vertebrae).
default_goal_eval_sho(check_movements_back).
default_goal_eval_sho(check_flexion).
default_goal_eval_sho(check_flexion_legs).
default_goal_eval_sho(check_bending_back).
default_goal_eval_sho(check_pedal_movements).
default_goal_eval_sho(check_neurological_examination).
default_goal_eval_sho(check_slr).
/* DEFAULT_GOAL of the GP trainee */
default_goal_eval_gpt(check_diagnose_patient).
default_goal_eval_gpt(check_history).
default_goal_eval_gpt(check_back_pain_history).
default_goal_eval_gpt(check_characteristics_pain).
default_goal_eval_gpt(check_severity_pain).
default_goal_eval_gpt(check_episodic_continue_pain).
default_goal_eval_gpt(check_location_pain).
default_goal_eval_gpt(check_radiation_pain).
default_goal_eval_gpt(check_relieving_factors).
default_goal_eval_gpt(check_aggravating_factors).
default_goal_eval_gpt(check_previous_back_pain).
default_goal_eval_gpt(check_similar_pain).
default_goal_eval_gpt(check_waterwork_infections_problems).
default_goal_eval_gpt(check_current_waterwork_infections).
default_goal_eval_gpt(check_physical_examination).
default_goal_eval_gpt(check_examination_back).
default_goal_eval_gpt(check_palpation).
default_goal_eval_gpt(check_palpation_vertebrae).
default_goal_eval_gpt(check_neurological_examination).
default_goal_eval_gpt(check_slr).
default_goal_eval_gpt(check_abdominal_exmaination).
default_goal_eval_gpt(check_palpation_kidneys).
default_goal_eval_gpt(check_investigations).
default_goal_eval_gpt(check_samples).
default_goal_eval_gpt(check_urine_sample).

/* DEFAULT_GOAL of the expert consultant */
default_goal_eval_expert(check_diagnose_patient).
default_goal_eval_expert(check_history).
default_goal_eval_expert(check_back_pain_history).
default_goal_eval_expert(check_characteristics_pain).
default_goal_eval_expert(check_duration_pain).
default_goal_eval_expert(check_severity_pain).
default_goal_eval_expert(check_episodic_continue_pain).
default_goal_eval_expert(check_location_pain).
default_goal_eval_expert(check_radiation_pain).
default_goal_eval_expert(check_radiation_previous_pain).
default_goal_eval_expert(check_radiation_previous_pain_more).
default_goal_eval_expert(check_relieving_factors).
default_goal_eval_expert(check_aggravating_factors).
default_goal_eval_expert(check_previous_back_pain).
default_goal_eval_expert(check_similar_pain).
default_goal_eval_expert(check_similar_pain_more).
default_goal_eval_expert(check_waterwork_infections_problems).
default_goal_eval_expert(check_current_waterwork_infections).
default_goal_eval_expert(check_past_waterwork_infections).
default_goal_eval_expert(check_back_pain_with_waterwork_infection).
default_goal_eval_expert(check_treatment_previous_back_pain).
default_goal_eval_expert(check_past_medical_history).
default_goal_eval_expert(check_general_health).
default_goal_eval_expert(check_general_health_more).
default_goal_eval_expert(check_appetite_habits).
default_goal_eval_expert(check_past_illnesses).
default_goal_eval_expert(check_kidney_problems).
default_goal_eval_expert(check_bowel).
default_goal_eval_expert(check_gyne).
default_goal_eval_expert(check_gyne_more).
default_goal_eval_expert(check_age).
default_goal_eval_expert(check_age_more).
default_goal_eval_expert(check_nationality).
default_goal_eval_expert(check_occupation).
default_goal_eval_expert(check_recent_occupation).
default_goal_eval_expert(check_physical_examination).
default_goal_eval_expert(check_general_examination).
default_goal_eval_expert(check_cardio_vascular_examination).
default_goal_eval_expert(check_respiratory_examination).
default_goal_eval_expert(check_gastro_intestinal_examination).
default_goal_eval_expert(check_examination_back).
default_goal_eval_expert(check_palpation).
default_goal_eval_expert(check_posture).
default_goal_eval_expert(check_flexion).
default_goal_eval_expert(check_bending_back).
default_goal_eval_expert(check_rotation).
default_goal_eval_expert(check_touch_toes).
default_goal_eval_expert(check_neurological_examination).
default_goal_eval_expert(check_reflexes).
default_goal_eval_expert(check_reflexes_lower_limbs).
default_goal_eval_expert(check_slr).
default_goal_eval_expert(check_power).
default_goal_eval_expert(check_sensation).
default_goal_eval_expert(check_investigations).
default_goal_eval_expert(check_xrays).
default_goal_eval_expert(check_pelvis_xrays).
default_goal_eval_expert(check_chest_xrays).
default_goal_eval_expert(check_lower_back_xrays).
default_goal_eval_expert(check_samples).
default_goal_eval_expert(check_blood_sample).
default_goal_eval_expert(check_esr).
default_goal_eval_expert(check_crp).
default_goal_eval_expert(check_bone_biochemistry).
default_goal_eval_expert(check_urine_sample).
default_goal_eval_expert(check_ultrasound).
default_goal_eval_expert(check_ultrasound_kidney).
default_goal_eval_expert(check_ivp).
default_goal_eval_expert(check_bone_scan).
APPENDIX B2: MEDICAL KNOWLEDGE AND GOALS OF THE FIRST 5TH YEAR STUDENT

This appendix contains the medical knowledge and the goals slots used to generate the goals and strategies of the first 5th year student. The two plans corresponding to her protocol and generated by the system can be found in appendices C2 and C3.

Medical knowledge

1. Hypotheses
kinds(hypothesis, urinary_infection).
kinds(hypothesis, sciatica).
kinds(hypothesis, congenital_abnormality).
kinds(hypothesis, hip_problem).
kinds(hypothesis, arthritis_of_hip).
kinds(hypothesis, recurrence_slipped_disc).
kinds(hypothesis, slipped_disc).
kinds(hypothesis, kidney_condition).
kinds(hypothesis, stone).
kinds(hypothesis, infection).
kinds(hypothesis, kidney_problem).

2. Knowledge about observations
kinds(symptom, patient_has_similar_pain).
kinds(symptom, tenderness_from_lumbar_spine_over_renal_area).
kinds(symptom, onset_pain_this_morning).
kinds(symptom, no_radiation_pain).
kinds(symptom, sudden_pain).
kinds(symptom, no_aggravating_factor).
kinds(symptom, no_waterwork_infection_symptom).
kinds(symptom, past_waterwork_infection).
kinds(symptom, left_kidney_missing).

kinds(sign, flexion_ok).
kinds(sign, slr_slightly_reduced).
3. Relations between hypotheses
kinds(infection, urinary_infection).
kinds(hip_problem, arthritis_of_hip).

4. Relations between observations
kinds_obs(patient_has_similar_pain, recurrent_similar_pain).
kinds_obs(tenderness_from_lumbar_spine_over_renal_area, muscle_spasm).

5. Relations between action slots of the goals and observations
kinds_obs(ask_onset_pain_by_5thy_student, refine_to_sudden_or_gradual_event).
kinds_obs(ask_relieving_factor_by_5thy_student, routine_protocol_for_analysis_of_pain).
kinds_obs(ask_aggravating_factor, routine_protocol_for_analysis_of_pain).
kinds_obs(ask_waterwork_infection_symptom, refine_burning_sensation_when_passing_water).

6. Relations between observations and hypotheses
causes(patient_has_similar_pain, slipped_disc).
causes(sudden_pain, slipped_disc).
causes(left_kidney_missing, congenital_abnormality).
causes(past_waterwork_infection,infection).

7. Relations between action slots and diseases
causes(ask_gradual_event, kidney_problem).
causes(ask_radiation_pain_by_5thy_student, sciatica).
causes(ask_tenderness_right_kidney, urinary_infection).
causes(ask_flexion_not_ok, hip_problem).
causes(ask_slr_reduced, arthritis_of_hip).
causes(ask_result_xray_back, recurrence_slipped_disc).
causes(ask_positive_urine_sample, kidney_condition).
causes(ask_positive_abdominal_xray, stone).

8. Knowledge to recognise that confirmation and elimination strategies have been applied
negative_rs3(past_waterwork_infection, no_past_waterwork_infection).
negative(ask_flexion_not_ok, flexion_ok).
negative(ask_positive_urine_sample, ask_negative_urine_sample).
negative(ask_positive_abdominal_xray, ask_negative_abdominal_xray).

9. Details about the action slots of the goals
details_action(ask_palpation_back, ask_tenderness_right_kidney).
details_action(ask_flexion, ask_flexion_not_ok).
details_action(ask_slr_by_5thy_student, ask_slr_reduced).
details_action(ask_urine_sample, ask_positive_urine_sample).
details_action(ask_abdominal_xray, ask_positive_abdominal_xray).
details_action(ask_xrays_back, ask_result_xray_back).

The goals of the first 5th year student
The structure of a goal is: goal(Name, Precursors, Subgoals, Actions, Effects)

/* CHECK DIAGNOSE PATIENT */
goal_5th1(check_diagnose_patient, [], [check_history, check_physical_examination, check_investigations], [], []).

/* CHECK HISTORY */
goal_5th1(check_history, [], [check_back_pain_history, check_past_medical_history], [], []).

/* CHECK BACK PAIN HISTORY */
goal_5th1(check_back_pain_history, [], [check_characteristics_pain, check_previous_back_pain], [], []).

/* CHECK CHARACTERISTICS OF THE PAIN */
goal_5th1(check_characteristics_pain, [], [check_duration_pain, check_radiation_pain, check_relieving_factors, check_aggravating_factors], [], []).

/* CHECK DURATION OF THE PAIN */
goal_5th1(check_duration_pain, [], [check_sudden_onset, check_gradual_onset], ask_onset_pain_by_5thy_student, [onset_pain_this_morning]).

/* CHECK SUDDEN ONSET */
goal_5th1(check_sudden_onset, [patient_has_similar_pain], [], ask_sudden_event, [sudden_pain]).
/* CHECK GRADUAL ONSET */
goal_5th1(check_gradual_onset,[sudden_pain],[],ask_gradual_event,[no_gradual_pain]).

/* CHECK RADIATION OF THE PAIN */
goal_5th1(check_radiation_pain,[no_aggravating_factor],[],ask_radiation_pain_by_5th_student,[no_radiation_pain]).

/* CHECK RELIEVING FACTORS */
goal_5th1(check_relieving_factors,[gradual_pain],[],ask_relieving_factor_by_5th_student,[paracetamol_did_not_help,no_relieving_factor]).

/* CHECK AGGRAVATING FACTORS */
goal_5th1(check_aggravating_factors,[paracetamol_did_not_help,no_relieving_factor],[],ask_aggravating_factor,[no_aggravating_factor]).

/* CHECK PREVIOUS BACK PAIN */
goal_5th1(check_previous_back_pain,[onset_pain_this_morning],[check_similar_pain,check_waterwork_infections_problems],[effects_previous_back_pain]).

/* CHECK SIMILAR PAIN */
goal_5th1(check_similar_pain,[effects_previous_back_pain],[],ask_similar_back_pain_by_5th_student,[patient_has_similar_pain]).

/* CHECK WATERWORK INFECTIONS */
goal_5th1(check_waterwork_infections_problems,[left_kidney_missing],[check_current_waterwork_infections,check_past_waterwork_infections],[effects_waterwork_infections_problems]).

/* CHECK CURRENT WATERWORK INFECTIONS */
goal_5th1(check_current_waterwork_infections,[effects_waterwork_infections_problems],[],ask_waterwork_infection_symptom,[no_waterwork_infection_symptom]).

/* CHECK PAST WATERWORK INFECTIONS */
goal_5th1(check_past_waterwork_infections,[no_waterwork_infection_symptom],[],ask_previous_back_problems_by_5th_student,[past_waterwork_infection]).

/* CHECK PAST MEDICAL HISTORY*/
goal_5th1(check_past_medical_history,[no_radiation_pain],[check_kidney_problems],[],[effects_past_medical_history]).

/** CHECK KIDNEY PROBLEMS */
goal_5th1(check_kidney_problems,[effects_past_medical_history],[],ask_kidney_problems_by_5thy_student,[left_kidney_missing]).

/** CHECK PHYSICAL EXAMINATION */
goal_5th1(check_physical_examination,[no_waterwork_infection_symptom],[check_examination_back,check_neurological_examination],[],[]).

/** CHECK EXAMINATION OF THE BACK */
goal_5th1(check_examination_back,[],[check_palpation,check_flexion],[],[])

/** CHECK PALPATION */
goal_5th1(check_palpation,[],[],ask_palpation_back,[tenderness_from_lumbar_spine_over_renal_area]).

/** CHECK FLEXION */
goal_5th1(check_flexion,[tenderness_from_lumbar_spine_over_renal_area],[],ask_flexion,[flexion_ok]).

/** CHECK NEUROLOGICAL EXAMINATION */
goal_5th1(check_neurological_examination,[],[check_slr],[],[])

/** CHECK SLR */
goal_5th1(check_slr,[],[],ask_slr_by_5thy_student,[slr_slightly_reduced]).

/** CHECK INVESTIGATIONS */
goal_5th1(check_investigations,[slr_slightly_reduced],[check_xrays,check_samples],[[],[effects_investigations]]).

/** CHECK X-RAYS */
goal_5th1(check_xrays,[effects_investigations],[check_back_xrays,check_abdominal_xrays],[[],[]]).

/** CHECK BACK X-RAYS */
goal_5th1(check_back_xrays,[],[],ask_xrays_back,[result_xray_back]).
/* CHECK ABDOMINAL X-RAYS */
goal_5th1(check_abdominal_xrays,[],[],ask_abdominal_xray, [result_abdominal_xray]).

/* URINE SAMPLES */
goal_5th1(check_samples,[result_abdominal_xray],[check_urine_sample],[],[]).

/* CHECK URINE SAMPLE */
goal_5th1(check urine_sample,[],[],ask urine_sample, [result urine_sample]).
APPENDIX B3: PROCEDURES TO GENERATE THE PLANS OF THE FIRST 5TH YEAR STUDENT

1. Procedures to generate the goals of the first 5th year ordered according to the physician's protocol. Similar procedures are used for the other levels of expertise.

/* BEGIN_DIAGNOSE calls another procedure that will process the goals. When all the goals have been processed, the system generates the level of expertise of the physician. */

begin_diagnose_5th1(Goal):- do_goal_5th1([],Goal).

begin_diagnose_5th1(Goal):-
  nl,nl,
  Level = 'fifth_year_medical_student',
  print_level_expertise(Level),
  print_hypotheses(),
  keep_hypotheses_5th1().

/* DO_GOAL */
/* stopping condition */
do_goal_5th1(Effects_collects,[]).

/* DO_GOAL takes a goal, checks that it has not be used, calls a procedure that checks that the precursors have been satisfied, calls a procedure that executes the goal by generating the associated strategies and interactions of strategies, adds the goals to the list of used goals and takes the new goal whose effect slot corresponds to the precursor slot of the given goal. */
do_goal_5th1(Effects_collected, New_goal):-
goal_5th1(Goal, Preconditions, Subgoals, Action, Effects),
not(used(goal_5th1(Goal, Preconditions, Subgoals, Action, Effects))),
satisfied(Preconditions, Effects_collected),
execute_goal_5th1(Goal,Preconditions,Subgoals,Action,Effects,Effects_collected, New_effects),
assert(used(goal_5th1(Goal, Preconditions, Subgoals, Action, Effects))),
do_goal_5th1(New_effects, New_goal).

/* DO_GOAL takes a goal, executes that goal by generating its associated strategies and interactions of strategies, adds it to the list of used goals and takes a new goal from the list of default goal. */

do_goal_5th1(Effects_collected, New_goal):-
choose_default_goal_5th1(Goal, Preconditions, Subgoals, Action, Effects),
execute_goal_5th1(Goal, Preconditions, Subgoals, Action, Effects, Effects_collected, New_effects),
assert(used(goal_5th1(Goal, Preconditions, Subgoals, Action, Effects))),
do_goal_5th1(New_effects, New_goal).

/* SATISFIED checks that the precursor of a goal is a member of the effects already collected i.e. whose goal has been triggered. */
satisfied(Preconditions, Effects_collected):-
Effects_collected \== [],
member(Preconditions, Effects_collected).

/* EXECUTE_GOAL adds the effect slot of the goal to the list of effects already collected, and then calls another procedure to generate and print the strategies and interactions of strategies associated with the goal. */

execute_goal_5th1(Goal, Preconditions, Subgoals, Action, Effects, Effects_collected, New_effects):-
append(Effects, Effects_collected, New_effects),
print_head_5th1(goal_5th1(Goal, Preconditions, Subgoals, Action, Effects)),!.

/* CHOOSE_DEFAULT_GOAL takes the next goal to be processed from the list of default goals and checks that it has not been used yet. */
choose_default_goal_5th1(Goal, Preconditions, Subgoals, Action, Effects):-
default_goal_5th1(Goal),
goal_5th1(Goal, Preconditions, Subgoals, Action, Effects),
not(used(goal_5th1(Goal, Preconditions, Subgoals, Action, Effects))).

/* PRINT_HEAD prints the goal name and calls another procedure to generate the strategies and interactions of strategies associated with it. */
print_head_5th1(goal_5th1(Goal,Preconditions,Subgoals,Action, Effects)):-
    nl, write('Goal: '), write(Goal), nl,
    get_goal_bis5th1(Goal, Action, Observation) .

/* GET_GOAL_BIS takes a goal and generates and prints the strategies and interactions of
strategies associated with it. */

get_goal_bis5th1(Goal,Action, Observation):-
goal_5th1(Goal,_,Action,Observation),
get_rs7([Goal,Observation,Action]),!.

get_goal_bis5th1(Goal,Action, Observation).

2. Procedures to generate the goals of the first 5th year generated according
to the default plan

/* INTERACTION_STRATEGY takes each goal at a time (see appendix B2) and finds the
strategies and interactions of strategies associated with it. */

interaction_strategy_5th1:-
    write('FIRST 5TH YEAR MEDICAL STUDENT'), nl,
    get_goal_5th1,
    fail.

/* GET_GOAL generates and prints the strategies and interactions of strategies for a given
goal. When all the goals have been processed, the system generates the level of expertise
of the physician as well as the list of hypotheses and the list of the differential. */

get_goal_5th1:-
goal_5th1(Goal,_,Action,Observation),
get_rs7([Goal,Observation,Action]).

get_goal_5th1:-
    nl,nl,
    Level = 'fifth_year_medical_student',
    print_level_expertise(Level),
    print_hypotheses,
3. Additional procedures

/* PRINT_LEVEL_EXPERTISE prints the level of expertise for the given sets of goals. */
print_level_expertise(Level):-
level_expertise(L),
write('Level of expertise of the '), write(Level), write(' is: '),
write(level_expertise(L)), nl, nl.

/* PRINT_HYPOTHESIS prints the hypotheses and the differential generated after the
goals and associated strategies have been generated for a given protocol */

print_hypotheses():-
write('The list of hypotheses generated is: '), nl,
list_hypotheses(LH),
write(list_hypotheses(LH)), nl, nl,
write('The list of hypotheses in the differential is: '),
differential_diagnosis(DD),
write(differential_diagnosis(DD)), nl, nl, !.

/* KEEP_HYPOTHESES keeps track of the hypotheses generated for the given protocol
and updates the list of hypotheses and the differential. */

keep_hypotheses_5th1():-
list_hypotheses_5th1(L),
retract(list_hypotheses_5th1(L)),
list_hypotheses(LH),
assert(list_hypotheses_5th1(LH)),
differential_diagnosis_5th1(DIFF),
retract(differential_diagnosis_5th1(DIFF)),
differential_diagnosis(DD),
assert(differential_diagnosis_5th1(DD)), !.

/* Init initialises the list of hypotheses and the list of differential. */

init_fifth_year:-
write('Initialisation of 5th year student protocol'),
list_hypotheses_5th1(L),
assert(list_hypotheses_5th1([])),
retract(list_hypotheses_5th1(L)),
differential_diagnosis_5th1(D),
assert(differential_diagnosis_5th1([])),
retract(differential_diagnosis_5th1(D)),
nl, write('End of initialisation of 5th year student protocol'), nl.
APPENDIX B4: DEFINITIONS OF REASONING STRATEGIES

This appendix contains the procedures to generate the reasoning strategies.

1. Generalisation strategy: GEN

/* REASONING_STRATEGY1 searches for the parent hypothesis, checks that both parent and child exit in the data base and checks that the parent hypothesis is not already in the list of hypotheses. This procedure is called by GET_RS1 */

reasoning_strategy1([Goal, Observation, Action, Hypothesis, Hypothesis_before]):-
kinds(Hypothesis_before, Hypothesis),
kinds(hypothesis, Hypothesis_before),
already_in_list(Hypothesis_before).

/* GET_RS1 applies the generalisation strategy and prints it out */

get_rs1([Goal, Observation, Action, Hypothesis]):-
reasoning_strategy1([Goal, Observation, Action, Hypothesis, Hypothesis_before]),
details_action(Action, Action_detail),

nl, write('STRATEGY: GEN'),
nl, write('Goal: '), write(Goal), nl,
write('Hypothesis child: '), write(Hypothesis), nl,
write('Hypothesis parent: '), write(Hypothesis_before), nl,
write('Evidence: '), write(Action_detail), nl.

2. Specialisation strategy: SPEC

/* REASONING_STRATEGY2 applies the specialisation strategy. It searches for the child hypothesis, checks that both parent and child hypotheses exist in the data base and prints out the strategy */

/* Case that details_action is used */

reasoning_strategy2([Goal, Observation, Hypothesis, Hypothesis_after, Action]):-
kinds(Hypothesis, Hypothesis_after),
kinds(hypothesis, Hypothesis),
kinds(hypothesis, Hypothesis_after),
details_action(Action, Action_detail),

nl, write('STRATEGY: SPEC'), nl, write('Goal: '), write(Goal), nl,
write('Hypothesis parent: '), write(Hypothesis), nl,
write('Hypothesis child: '), write(Hypothesis_after), nl,
write('Evidence: '), write(Action_detail), nl, !.

/* Case that observation is used. */
reasoning_strategy2([Goal, Observation, Hypothesis, Hypothesis_after, Action]):-
kinds(Hypothesis, Hypothesis_after),
kinds(hypothesis, Hypothesis),
kinds(hypothesis, Hypothesis_after),
nl, write('STRATEGY: SPEC'), nl, write('Goal: '), write(Goal), nl,
write('Hypothesis parent: '), write(Hypothesis), nl,
write('Hypothesis child: '), write(Hypothesis_after), nl,
write('Evidence: '), write(Observation), nl.

3. Confirmation strategy: CONF

/* GET_RS3_INTERACTION to apply CONF in the case of the interaction HGN SPEC CONF. The procedure asserts the confirmed hypothesis in the differential diagnosis and prints it out. */
get_rs3_interaction([Goal, Hypothesis_after, Observation, Action, Opposite_observation]):-
negative_rs3(Observation, Opposite_observation), !,
differential_diagnosis(DD),
retract(differential_diagnosis(DD)),
assert(differential_diagnosis([Hypothesis_after | DD])),
nl, write('STRATEGY: CONF'), nl, write('Goal: '), write(Goal), nl,
write('Hypothesis confirmed: '), write(Hypothesis_after), nl,
write('Evidence: '), write(Observation), nl,
write('Differential Diagnosis: '),
write(differential_diagnosis([Hypothesis_after | DD])), nl.

/* GET_RS3_ANOTHER_INTERACTION to apply CONF in the case of the interaction HGN CONF. The procedure asserts the confirmed hypothesis in the differential diagnosis and prints it out. */
get_rs3_another_interaction([Goal, Hypothesis_after, Observation, Action, Opposite_observation]):-
negative_rs6(Observation, Opposite_observation), !,
differential_diagnosis(DD),
retract(differential_diagnosis(DD)),
assert(differential_diagnosis([Hypothesis_after | DD])),
nl, write('STRATEGY: CONF'), nl, write('Goal: '), write(Goal), nl,
write('Hypothesis confirmed: '), write(Hypothesis_after), nl,
write('Evidence: '), write(Observation), nl,
write('Differential Diagnosis: ')
write(differential_diagnosis([Hypothesis_after]), nl).

4. Elimination strategy: ELIM

/* GET_RS4_INTERACTION to apply ELIM in the case of the interaction HGN SPEC CONF ELIM. The procedure deletes the disconfirmed hypothesis from the differential diagnosis and prints the new differential diagnosis. */
get_rs4_interaction([Goal,Hypothesis_after,Observation,Action,Opposite_observation]):-
    negative_rs4(Observation, Opposite_observation),
    differential_diagnosis(DD),
    member([Hypothesis_after], DD),
    deleting(Hypothesis_after, DD, New_dd),
    retract(differential_diagnosis(DD)),
    assert(differential_diagnosis(New_dd)),
    nl, write('STRATEGY: ELIM'),nl,write('Goal: '), write(Goal), nl,
write('Hypothesis ruled out: '), write(Hypothesis_after), nl,
write('Evidence: '), write(Opposite_observation), nl,
write('Differential Diagnosis: ')
write(differential_diagnosis(New_dd), nl,
Level_expertise = 3,
set_level_expertise(Level_expertise).

/* GET_RS4_INTERACTION to apply ELIM in the case of the interaction HGN SPEC ELIM without CONF */
get_rs4_interaction([Goal,Hypothesis_after,[H_ob | T_ob],
Action,Opposite_observation]):-
    negative_rs4(H_ob, Opposite_observation),
    differential_diagnosis(DD), nl,
    write('STRATEGY: ELIM'),nl,write('Goal: '), write(Goal), nl,
    write('Hypothesis ruled out: '), write(Hypothesis_after), nl,
    write('Evidence: '), write(Opposite_observation), nl,
    write('Differential Diagnosis: ')
    write(differential_diagnosis(DD), nl,
Level_expertise = 3,
set_level_expertise(Level_expertise).
/* GET_RS4 to apply ELIM in the case of the interaction HGN ELIM (SPEC not applied).
The procedure is similar to GET_RS4_INTERACTION except that it does not include the
negative fact for ELIM. */
get_rs4([Goal, Hypothesis, Negative_observation, Action]):­
differential_diagnosis(DD),
member([Hypothesis_after], DD),
deleting(Hypothesis_after, DD, New_dd),
retract(differential_diagnosis(DD)),
assert(differential_diagnosis(New_dd)),
nl, write('STRATEGY: ELIM'), nl, write('Goal: '),
write(Goal), nl, write('Hypothesis ruled out: '), write(Hypothesis_after), nl,
write('Evidence: '), write(Negative_observation), nl,
write('Differential Diagnosis: '),
write(differential_diagnosis(New_dd)), nl, !.

5. Problem refinement: PREF
/* REASONING_STRATEGYS checks that the observation exists in the medical data base
and looks for the new observation. This procedure is called by GET_RS5 and
GET_RS5_INTERACTION. */

/* Case where observation is used */
reasoning_strategy5([Goal, Observation, Observation_after, Action, Ob_action]):­
kinds(Type, Observation),
kinds_obs(Observation, Observation_after),
Observation = Ob_action.

/* Case where action slot is used */
reasoning_strategy5([Goal, Observation, Observation_after, Action, Ob_action]):­
kinds(Type, Observation),
kinds_obs(Action, Observation_after),
Action = Ob_action.

/* GET_STRATEGYS applied the problem refinement strategy and prints it out. */
get_strategy5([Goal, Observation, Observation_after, Action, Ob_action]):­
reasoning_strategy5([Goal, Observation, Observation_after, Action, Ob_action]),
nl, write('STRATEGY: PREF'), nl, write('Goal: '), write(Goal), nl,
write('Observation/Action: '), write(Ob_action), nl,
write('Observation refined to or Routine protocol used: '), write(Observation_after), nl.
/* GET_RS5_INTERACTION to apply PREF in the case of the repetition of PREF */
/* Stopping condition */
get_rs5_interaction([Goal, Observation_after, Observation_further, Action]):-
  kinds_obs(Observation_after,[]).

/* GET_RS5_INTERACTION takes the new observation generated and searches for another observation that could be generated from that new one, and so on. */
get_rs5_interaction([Goal, Observation_after, Observation_further, Action]):-
  reasoning_strategy5([Goal, Observation_after, Observation_further, Action, Ob_action]), !,
  nl, write('STRATEGY: PREF (repetition)'), nl,
  write('Goal: '), write(Goal), nl,
  write('Observation: '), write(Observation_after), nl, write('Observation refined to or Routine protocol used: '),
  write(Observation_further), nl,
  Level_expertise = 4,
  set_level_expertise(Level_expertise),
  get_rs5_interaction([Goal, Observation_further, Observation_next, Action]).

6. Hypothesis generation: HGN
/* REASONING_STRATEGY6 checks that the observation exists in the medical data base, and searches for the hypothesis linked with that observation. This procedure is called by GET_RS6. */
reasoning_strategy6([Goal, Observation, Action, Obs_action, Hypothesis]):-
  kinds(Type,Observation),
  causes(Observation,Hypothesis),
  Observation = Obs_action.

/* In this case REASONING_STRATEGY6 gets the detail of the action slot, and looks for the hypothesis linked with the detail of action */
reasoning_strategy6([Goal, Observation, Action, Obs_action, Hypothesis]):-
  details_action(Action, Action_detail),
  causes(Action_detail,Hypothesis),
  Action_detail = Obs_action.

/* In this case REASONING_STRATEGY6 gets the hypothesis associated with the action. */
reasoning_strategy6([Goal, Observation, Action, Obs_action, Hypothesis]):­
causes(Action, Hypothesis),
Action = Obs_action.

/* GET_RS6 applies the hypothesis generation strategy then passes control to
CONTINUE_RS6 which will apply one of the interaction of strategies that are possible
from HGN. */
get_rs6([Goal, Observation, Action, Hypothesis]):­
reasoning_strategy6([Goal, Observation, Action, Obs_action, Hypothesis]),
nl, write('STRATEGY: HGN'), nl, write('Goal: '), write(Goal), nl,
write('Observation/Action: '), write(Obs_action), nl,
write('Hypothesis: '), write(Hypothesis), nl,
add_hypothesis_list_hypotheses(Hypothesis),
Level_expertise = 1,
set_level_expertise(Level_expertise),
continue_rs6([Goal, Observation, Action, Hypothesis]).

/* Repetition of HGN: Combining one observation with another observation (or a list of
observations) */
get_rs6([Goal, Observation, Action, Hypothesis]):­
causes([Observation | Tail_obs], Hypothesis),
nl, write('STRATEGY: HGN (repetition)'), nl,
write('Goal: '), write(Goal), nl,
write('Observation: '), write([Observation | Tail_obs]), nl,
write('Hypothesis: '), write(Hypothesis), nl,
Level_expertise = 4,
set_level_expertise(Level_expertise),
add_hypothesis_list_hypotheses(Hypothesis),
continue_rs6([Goal, Observation, Action, Hypothesis]).

/* case where action slot is used */
get_rs6([Goal, Observation, Action, Hypothesis]):­
causes([Action | Tail_obs], Hypothesis),
nl, write('STRATEGY: HGN (repetition)'), nl,
write('Goal: '), write(Goal), nl,
write('Observation/Action: '), write([Action | Tail_obs]), nl,
write('Hypothesis: '), write(Hypothesis), nl,
Level_expertise = 4,
set_level_expertise(Level_expertise),
add_hypothesis_list_hypotheses(Hypothesis),
continue_rs6([Goal, Observation, Action, Hypothesis]).

/* Case where details_action is used */
get_rs6([Goal, Observation, Action, Hypothesis]):-
details_action(Action, Action_detail),
causes([Action_detail | Tail_obs], Hypothesis),
nl, write('STRATEGY: HGN (repetition)'), nl,
write('Goal: '), write(Goal), nl,
write('Observation/Action: '), write([Action_detail | Tail_obs]), nl,
write('Hypothesis: '), write(Hypothesis), nl,
Level_expertise = 4,
set_level_expertise(Level_expertise),
add_hypothesis_list_hypotheses(Hypothesis),
continue_rs6([Goal, Observation, Action, Hypothesis]).

7. Anatomically based strategy: ANAT
/* REASONING_STRATEGY7 checks that the observation is in the data base and then gets the anatomical information linked to it. This procedure is called by GET_RS7. */
reasoning_strategy7([Goal, Observation, Anat]):-
kinds(Type, Observation),
anat(Observation, Anat).

/*GET_RS7 generates the anatomically based strategy and prints out the strategy. */
get_rs7([Goal, Observation, Action]):-
reasoning_strategy7([Goal, Observation, Anat]),
nl, write('STRATEGY: ANAT'), nl, write('Goal: '), write(Goal), nl,
write('Observation: '), write(Observation), nl,
write('Anatomical information: '), write(Anat),
nl, fail.
APPENDIX C1: INTERACTIONS OF STRATEGIES

This appendix contains examples of interactions of reasoning strategies at various levels of expertise that have been generated by the program.

1. Interactions of level 1: 3rd year student

Interaction ANAT HGN
STRATEGY: ANAT
Goal: check_kind_of_pain
Observation: [renal_pain]
Anatomical information: renal_pain_is_obstructing_in_the_ureters

STRATEGY: HGN
Goal: check_kind_of_pain
Observation/Action: renal_pain
Hypothesis: infections
List of hypotheses: list_hypotheses([infections])

Interaction PREF HGN
STRATEGY: PREF
Goal: check_cardio_respiratory
Observation/Action: ask_cardiorespiratory_symptoms
Routine protocol used: routine_protocol_for_cardiorespiratory_symptoms

STRATEGY: HGN
Goal: check_cardio_respiratory
Observation/Action: ask_cardiorespiratory_symptoms
Hypothesis: eroding_aortic_aneurysm
List of hypotheses: list_hypotheses([eroding_aortic_aneurysm])
Interaction HGN SPEC

STRATEGY: HGN
Goal: check_kind_of_pain
Observation/Action: renal_pain
Hypothesis: infections

List of hypotheses: list_hypotheses([infections])

STRATEGY: SPEC
Goal: check_kind_of_pain
Hypothesis parent: infections
Hypothesis child: descending_infection
Evidence: [renal_pain]

List of hypotheses: list_hypotheses([descending_infection, infections])

STRATEGY: SPEC
Goal: check_kind_of_pain
Hypothesis parent: infections
Hypothesis child: pyelonephritis
Evidence: [renal_pain]

List of hypotheses: list_hypotheses([pyelonephritis, descending_infection, infections])

2. Interaction of level 1 at level 2: 4th year student

Interaction ANAT HGN

STRATEGY: ANAT
Goal: check_movements_legs
Observation: [can_move_legs]
Anatomical information: details_spinal_hole_and_nerves

STRATEGY: HGN
Goal: check_movements_legs
Observation/Action: ask_movements_legs
Hypothesis: retroverted_prolapsed
List of hypotheses: list_hypotheses([retroverted_prolapsed])

3. Interactions of level 3: 5th year student

Interaction HGN ELIM
STRATEGY: HGN
Goal: check_abdominal_xrays
Observation/Action: ask_positive_abdominal_xray
Hypothesis: stone

List of hypotheses: list_hypotheses([stone])

Differential Diagnosis: differential_diagnosis([stone])

STRATEGY: ELIM
Goal: check_abdominal_xrays
Hypothesis ruled out: stone
Evidence: ask_negative_abdominal_xray
Differential Diagnosis: differential_diagnosis([])

Interaction HGN ELIM SPEC
STRATEGY: HGN
Goal: check_flexion
Observation/Action: ask_flexion_not_ok
Hypothesis: hip_problem

List of hypotheses: list_hypotheses([hip_problem])

Differential Diagnosis: differential_diagnosis([hip_problem])

STRATEGY: ELIM
Goal: check_flexion
Hypothesis ruled out: hip_problem
Evidence: flexion_ok
Differential Diagnosis: differential_diagnosis([])
STRA\-TEGY: SPEC
Goal: check_flexion
Hypothesis parent: hip_problem
Hypothesis child: arthritis_of_hip
Evidence: ask_flexion_not_ok

List of hypotheses: list_hypotheses([arthritis_of_hip, hip_problem])

Interaction HGN SPEC CONF ELIM
STRA\-TEGY: HGN
Goal: check_past_waterwork_infections
Observation/Action: past_waterwork_infection
Hypothesis: infection

List of hypotheses: list_hypotheses([infection])

STRA\-TEGY: SPEC
Goal: check_past_waterwork_infections
Hypothesis parent: infection
Hypothesis child: urinary_infection
Evidence: [past_waterwork_infection]

List of hypotheses: list_hypotheses([urinary_infection, infection])

STRA\-TEGY: CONF
Goal: check_past_waterwork_infections
Hypothesis confirmed: urinary_infection
Evidence: past_waterwork_infection
Differential Diagnosis: differential_diagnosis([urinary_infection])

STRA\-TEGY: ELIM
Goal: check_past_waterwork_infections
Hypothesis ruled out: urinary_infection
Evidence: past_waterwork_infections
Differential Diagnosis: differential_diagnosis([])
4. Interactions of level 4: House Officer

Interaction HGN's

STRATEGY: HGN (repetition)
Goal: check_feeling_hot_sweaty
Observation/Action: [ask_feel_hot_sweaty_sick, pain_in_back]
Hypothesis: kidney_infection

List of hypotheses: list_hypotheses([kidney_infection])

Interaction HGN SPEC ELIM GEN

STRATEGY: HGN
Goal: check_accident_back
Observation/Action: ask_injured_back
Hypothesis: inflammatory_condition

List of hypotheses: list_hypotheses([inflammatory_condition])

STRATEGY: SPEC
Goal: check_accident_back
Hypothesis parent: inflammatory_condition
Hypothesis child: pyelonephritis_inflammation
Evidence: ask_injured_back

List of hypotheses: list_hypotheses([pyelonephritis_inflammation, inflammatory_condition])

STRATEGY: ELIM
Goal: check_accident_back
Hypothesis ruled out: pyelonephritis_inflammation
Evidence: ask_no_accident_back
Differential Diagnosis: differential_diagnosis([])

STRATEGY: GEN
Goal: check_accident_back
Hypothesis child: pyelonephritis_inflammation
Hypothesis parent: serious_problems
Evidence: ask_injured_back

Interaction PREF's
STRATEGY: PREF
Goal: check_palpation_muscle
Observation/Action: tenderness_and_spasms
Observation refined to or Routine protocol used: muscle_tenderness

STRATEGY: PREF (repetition)
Goal: check_palpation_muscle
Observation: muscle_tenderness
Observation refined to or Routine protocol used: muscular_pain

5. Interactions of level 5: General Practitioner

Interaction HGN CONF
STRATEGY: HGN
Goal: check_similar_pain
Observation/Action: similar_pain
Hypothesis: similar_disc_problem

List of hypotheses: list_hypotheses(similar_disc_problem)

STRATEGY: CONF
Goal: check_similar_pain
Hypothesis confirmed: similar_disc_problem
Evidence: similar_pain
Differential Diagnosis: differential_diagnosis(similar_disc_problem)

Interaction HGN GEN
STRATEGY: HGN (repetition)
Goal: check_aggravating_relieving_factors
Observation: no_aggravating_or_relieving_factor,onset_pain_this_morning,previous_back_problems,similar_pain,sharp_pain,right_sided_back_pain, no_radiation_pain]
Hypothesis: acute_back_strain

List of hypotheses: list_hypotheses([acute_back_strain])

STRATEGY: GEN
Goal: check_aggravating_relieving_factors
Hypothesis child: acute_back_strain
Hypothesis parent: muscularskeletal
Evidence: characteristics_pain

6. Common Interactions

Common interaction of level 1 - PREF HGN
5th year student
STRATEGY: PREF
Goal: check_similar_pain
Observation/Action: patient_has_similar_pain
Observation refined to or Routine protocol used: recurrent_similar_pain

STRATEGY: HGN
Goal: check_similar_pain
Observation/Action: patient_has_similar_pain
Hypothesis: slipped_disc

List of hypotheses: list_hypotheses([slipped_disc])

Common interaction of level 3 - HGN ELIM
General practitioner
STRATEGY: HGN
Goal: check_radiation_previous_pain
Observation/Action: ask_radiation_previous_back_pain
Hypothesis: acute_sciatic

List of hypotheses: list_hypotheses([acute_sciatic])

Differential Diagnosis: differential_diagnosis([acute_sciatic])
STRATEGY: ELIM
Goal: check_radiation_previous_pain
Hypothesis ruled out: acute_sciatric
Evidence: no_radiation_pain_previous
Differential Diagnosis: differential_diagnosis([])

Common interaction of level 4 - HGN's
General practitioner
STRATEGY: HGN (repetition)
Goal: check_treatment_previous_pain
Observation:
[[treat_week_bed,treat_pain_killers,treat_no_tests,
treat_no_physiotherapy,treat_no_xrays,
no_radiation_previous_back_pain,no_back_pain_until_now],
[sharp_pain,right_sided_back_pain,no_radiation_pain,
no_aggravating_or_relieving_factor]]
Hypothesis: bit_of_ligament_strain

List of hypotheses: list_hypotheses([bit_of_ligament_strain])
APPENDIX C2: PLAN OF THE FIRST 5TH YEAR MEDICAL STUDENT

This appendix shows the plan of the first 5th year medical student. The goals are ordered according to the physician’s protocol. The plan contains the goals and their associated strategies applied by the student. Some goals have reasoning strategies associated with them while other goals do not. The graphical representation of the student's plan is in appendix A7, the list of her goals in appendix B1 and the medical knowledge and goals slots in appendix B2. The system starts with the goal check_diagnose_patient.

Goal: check_diagnose_patient

Goal: check_history

Goal: check_back_pain_history

Goal: check_characteristics_pain

Goal: check_duration_pain

STRATEGY: PREF
Goal: check_duration_pain
Observation/Action: ask_onset_pain_by_5thy_student
Observation refined to or Routine protocol used: refine_to_sudden_or_gradual_event

Goal: check_previous_back_pain

Goal: check_similar_pain

STRATEGY: PREF
Goal: check_similar_pain
Observation/Action: patient_has_similar_pain
Observation refined to or Routine protocol used: recurrent_similar_pain

STRATEGY: HGN
Goal: check_similar_pain
Observation/Action: patient_has_similar_pain
Hypothesis: slipped_disc

List of hypotheses: list_hypotheses([slipped_disc])

Goal: check_sudden_onset

STRATEGY: HGN
Goal: check_sudden_onset
Observation/Action: sudden_pain
Hypothesis: slipped_disc

Goal: check_gradual_onset

STRATEGY: HGN
Goal: check_gradual_onset
Observation/Action: ask_gradual_event
Hypothesis: kidney_problem

List of hypotheses: list_hypotheses([kidney_problem, slipped_disc])

Goal: check_relieving_factors

STRATEGY: PREF
Goal: check_relieving_factors
Observation/Action: ask_relieving_factor_by_5thy_student
Observation refined to or Routine protocol used: routine_protocol_for_analysis_of_pain

Goal: check_aggravating_factors

STRATEGY: PREF
Goal: check_aggravating_factors
Observation/Action: ask_aggravating_factor
Observation refined to or Routine protocol used: routine_protocol_for_analysis_of_pain

Goal: check_radiation_pain

STRATEGY: HGN
Goal: check_radiation_pain
Observation/Action: ask_radiation_pain_by_5th_year_student
Hypothesis: sciatica

List of hypotheses: list_hypotheses([sciatica, kidney_problem, slipped_disc])

Goal: check_past_medical_history

Goal: check_kidney_problems

STRATEGY: HGN
Goal: check_kidney_problems
Observation/Action: left_kidney_missing
Hypothesis: congenital_abnormality

List of hypotheses: list_hypotheses([congenital_abnormality, sciatica, kidney_problem, slipped_disc])

Goal: check_waterwork_infections_problems

Goal: check_current_waterwork_infections

STRATEGY: PREF
Goal: check_current_waterwork_infections
Observation/Action: ask_waterwork_infection_symptom
Observation refined to or Routine protocol used: refine_burning_sensation_when_passing_water

Goal: check_past_waterwork_infections

STRATEGY: HGN
Goal: check_past_waterwork_infections
Observation/Action: past_waterwork_infection
Hypothesis: infection

List of hypotheses: list_hypotheses([infection, congenital_abnormality, sciatica, kidney_problem, slipped_disc])

STRATEGY: SPEC
Goal: check_past_waterwork_infections
Hypothesis parent: infection
Hypothesis child: urinary_infection
Evidence: [past_waterwork_infection]

List of hypotheses: list_hypotheses([urinary_infection, infection, congenital_abnormality, sciatica, kidney_problem, slipped_disc])

STRATEGY: CONF
Goal: check_past_waterwork_infections
Hypothesis confirmed: urinary_infection
Evidence: past_waterwork_infection
Differential Diagnosis: differential_diagnosis([urinary_infection])

STRATEGY: ELIM
Goal: check_past_waterwork_infections
Hypothesis ruled out: urinary_infection
Evidence: past_waterwork_infections
Differential Diagnosis: differential_diagnosis([])

Goal: check_physical_examination

Goal: check_examination_back

Goal: check_palpation

STRATEGY: PREF
Goal: check_palpation
Observation/Action: tenderness_from_lumbar_spine_over_renal_area
Observation refined to or Routine protocol used: muscle_spasm

STRATEGY: HGN
Goal: check_palpation
Observation/Action: ask_tenderness_right_kidney
Hypothesis: urinary_infection

Goal: check_flexion
STRATEGY: HGN
Goal: check flexion
Observation/Action: ask flexion not ok
Hypothesis: hip problem

List of hypotheses: list_hypotheses([hip_problem, urinary_infection, infection, congenital_abnormality, sciatica, kidney_problem, slipped_disc])

Differential Diagnosis: differential_diagnosis([hip_problem])

STRATEGY: ELIM
Goal: check flexion
Hypothesis ruled out: hip problem
Evidence: flexion ok
Differential Diagnosis: differential_diagnosis([])

STRATEGY: SPEC
Goal: check flexion
Hypothesis parent: hip_problem
Hypothesis child: arthritis_of_hip
Evidence: ask flexion not ok

List of hypotheses: list_hypotheses([arthritis_of_hip, hip_problem, urinary_infection, infection, congenital_abnormality, sciatica, kidney_problem, slipped_disc])

Goal: check neurological examination

Goal: check slr

STRATEGY: HGN
Goal: check slr
Observation/Action: ask slr reduced
Hypothesis: arthritis_of_hip

Goal: check investigations

Goal: check xrays
Goal: check_back_xrays

STRATEGY: HGN
Goal: check_back_xrays
Observation/Action: ask_result_xray_back
Hypothesis: recurrence_slipped_disc

List of hypotheses: list_hypotheses([recurrence_slipped_disc, arthritis_of_hip, hip_problem, urinary_infection, infection, congenital_abnormality, sciatica, kidney_problem, slipped_disc])

Goal: check_abdominal_xrays

STRATEGY: HGN
Goal: check_abdominal_xrays
Observation/Action: ask_positive_abdominal_xray
Hypothesis: stone

List of hypotheses: list_hypotheses([stone, recurrence_slipped_disc, arthritis_of_hip, hip_problem, urinary_infection, infection, congenital_abnormality, sciatica, kidney_problem, slipped_disc])

Differential Diagnosis: differential_diagnosis([stone])

STRATEGY: ELIM
Goal: check_abdominal_xrays
Hypothesis ruled out: stone
Evidence: ask_negative_abdominal_xray
Differential Diagnosis: differential_diagnosis(())

Goal: check_samples

Goal: check_urine_sample

STRATEGY: HGN
Goal: check_urine_sample
Observation/Action: ask_positive_urine_sample
Hypothesis: kidney_condition
List of hypotheses: list_hypotheses([kidney_condition, stone, recurrence_slipped_disc, arthritis_of_hip, hip_problem, urinary_infection, infection, congenital_abnormality, sciatica, kidney_problem, slipped_disc])

Differential Diagnosis: differential_diagnosis([kidney_condition])

STRATEGY: ELIM
Goal: check_urine_sample
Hypothesis ruled out: kidney_condition
Evidence: ask_negative_urine_sample
Differential Diagnosis: differential_diagnosis([])

Level of expertise of the fifth_year_medical_student is: level_expertise(3)

The list of hypotheses generated is:
list_hypotheses([kidney_condition, stone, recurrence_slipped_disc, arthritis_of_hip, hip_problem, urinary_infection, infection, congenital_abnormality, sciatica, kidney_problem, slipped_disc])

The list of hypotheses in the differential is: differential_diagnosis([])
This appendix shows the plan of the first 5th year student generated according to the default plan (see appendix A8). The plan contains the goals and their associated strategies applied by the student. The graphical representation of the student's plan is in appendix A7, the list of her goals in appendix B1 and the medical knowledge and goals slots in appendix B2.

**FIRST 5TH YEAR MEDICAL STUDENT**

**STRATEGY: PREF**
Goal: check_duration_pain
Observation/Action: ask_onset_pain_by_5thy_student
Observation refined to or Routine protocol used: refine_to_sudden_or_gradual_event

**STRATEGY: HGN**
Goal: check_sudden_onset
Observation/Action: sudden_pain
Hypothesis: slipped_disc

List of hypotheses: list_hypotheses([slipped_disc])

**STRATEGY: HGN**
Goal: check_gradual_onset
Observation/Action: ask_gradual_event
Hypothesis: kidney_problem

List of hypotheses: list_hypotheses([kidney_problem, slipped_disc])

**STRATEGY: HGN**
Goal: check_radiation_pain
Observation/Action: ask_radiation_pain_by_5thy_student
Hypothesis: sciatica

List of hypotheses: list_hypotheses([sciatica, kidney_problem, slipped_disc])
STRATEGY: PREF
Goal: check_relieving_factors
Observation/Action: ask_relieving_factor_by_5th_student
Observation refined to or Routine protocol used: routine_protocol_for_analysis_of_pain

STRATEGY: PREF
Goal: check_aggravating_factors
Observation/Action: ask_aggravating_factor
Observation refined to or Routine protocol used: routine_protocol_for_analysis_of_pain

STRATEGY: PREF
Goal: check_similar_pain
Observation/Action: patient_has_similar_pain
Observation refined to or Routine protocol used: recurrent_similar_pain

STRATEGY: HGN
Goal: check_similar_pain
Observation/Action: patient_has_similar_pain
Hypothesis: slipped_disc

STRATEGY: PREF
Goal: check_current_waterwork_infections
Observation/Action: ask_waterwork_infection_symptom
Observation refined to or Routine protocol used: refine_burning_sensation_when_passing_water

STRATEGY: HGN
Goal: check_past_waterwork_infections
Observation/Action: past_waterwork_infection
Hypothesis: infection

List of hypotheses: list_hypotheses([infection, sciatica, kidney_problem, slipped_disc])

STRATEGY: SPEC
Goal: check_past_waterwork_infections
Hypothesis parent: infection
Hypothesis child: urinary_infection
Evidence: [past_waterwork_infection]
List of hypotheses: list_hypotheses([urinary_infection, infection, sciatica, kidney_problem, slipped_disc])

STRATEGY: CONF
Goal: check_past_waterwork_infections
Hypothesis confirmed: urinary_infection
Evidence: past_waterwork_infection
Differential Diagnosis: differential_diagnosis([urinary_infection])

STRATEGY: ELIM
Goal: check_past_waterwork_infections
Hypothesis ruled out: urinary_infection
Evidence: past_waterwork_infections
Differential Diagnosis: differential_diagnosis([])

STRATEGY: HGN
Goal: check_kidney_problems
Observation/Action: left_kidney_missing
Hypothesis: congenital_abnormality

List of hypotheses: list_hypotheses([congenital_abnormality, urinary_infection, infection, sciatica, kidney_problem, slipped_disc])

STRATEGY: PREF
Goal: check_palpation
Observation/Action: tenderness_from_lumbar_spine_over_renal_area
Observation refined to or Routine protocol used: muscle_spasm

STRATEGY: HGN
Goal: check_palpation
Observation/Action: ask_tenderness_right_kidney
Hypothesis: urinary_infection

STRATEGY: HGN
Goal: check_flexion
Observation/Action: ask_flexion_not_ok
Hypothesis: hip_problem
List of hypotheses: list_hypotheses([hip_problem, congenital_abnormality, urinary_infection, infection, sciatica, kidney_problem, slipped_disc])

Differential Diagnosis: differential_diagnosis([hip_problem])

STRATEGY: ELIM
Goal: check_flexion
Hypothesis ruled out: hip_problem
Evidence: flexion_ok
Differential Diagnosis: differential_diagnosis([])

STRATEGY: SPEC
Goal: check_flexion
Hypothesis parent: hip_problem
Hypothesis child: arthritis_of_hip
Evidence: ask_flexion_not_ok

List of hypotheses: list_hypotheses([arthritis_of_hip, hip_problem, congenital_abnormality, urinary_infection, infection, sciatica, kidney_problem, slipped_disc])

STRATEGY: HGN
Goal: check_slr
Observation/Action: ask_slr_reduced
Hypothesis: arthritis_of_hip

STRATEGY: HGN
Goal: check_back_xrays
Observation/Action: ask_result_xray_back
Hypothesis: recurrence_slipped_disc

List of hypotheses: list_hypotheses([recurrence_slipped_disc, arthritis_of_hip, hip_problem, congenital_abnormality, urinary_infection, infection, sciatica, kidney_problem, slipped_disc])

STRATEGY: HGN
Goal: check_abdominal_xrays
Observation/Action: ask_positive_abdominal_xray
Hypothesis: stone

List of hypotheses: list_hypotheses([stone, recurrence_slipped_disc, arthritis_ofHip, hip_problem, congenital_abnormality, urinary_infection, infection, sciatica, kidney_problem, slipped_disc])

Differential Diagnosis: differential_diagnosis([stone])

STRATEGY: ELIM
Goal: check_abdominal_xrays
Hypothesis ruled out: stone
Evidence: ask_negative_abdominal_xray
Differential Diagnosis: differential_diagnosis([])

STRATEGY: HGN
Goal: check_urine_sample
Observation/Action: ask_positive_urine_sample
Hypothesis: kidney_condition

List of hypotheses: list_hypotheses([kidney_condition, stone, recurrence_slipped_disc, arthritis_ofHip, hip_problem, congenital_abnormality, urinary_infection, infection, sciatica, kidney_problem, slipped_disc])

Differential Diagnosis: differential_diagnosis([kidney_condition])

STRATEGY: ELIM
Goal: check_urine_sample
Hypothesis ruled out: kidney_condition
Evidence: ask_negative_urine_sample
Differential Diagnosis: differential_diagnosis([])

Level of expertise of the fifth_year_medical_student is: level_expertise(3)

The list of hypotheses generated is:
list_hypotheses([kidney_condition, stone, recurrence_slipped_disc, arthritis_ofHip,
hip_problem, congenital_abnormality, urinary_infection, infection, sciatica,
kidney_problem, slipped_disc])

The list of hypotheses in the differential is: differential_diagnosis([])
APPENDIX D1: INSTRUCTIONS TO THE INDEPENDENT ASSESSOR

The independent assessor was given the following instructions:

This coding is for part 1 of the protocols only. The task is to associate goals from the list of goals with the protocol, and to report it on a predefined plan (see attached). A goal corresponds to a decision that is made to diagnose the patient. A plan consists of a hierarchy of these goals.

For each protocol, select an interaction between the patient and the subject (i.e. one question/answer or a set of questions/answers), and find from the list of goals, one (or more goals) which can be associated with it. Then report the line numbers on the predefined plan. Do not attempt to put a goal that does not fit (this would indicate that there may be a new goal not in the list): either leave it blank, or add what you think the goal is.

Example:
Protocol with 4th year student:

1 ET Laurence is going to act as a 42 year old who comes in complaining of back pain
2 ST Comes into hospital?
3 ET Yes.
4 ST When did this pain start?
5 PT It started this morning.

Associated goals:
1 to 3 no goal
4 to 5 check_duration_pain
1 to 5 check_diagnose_patient, check_history, check_back_pain_history, check_characterisics_pain
APPENDIX D2: LIST OF ADDITIONAL GOALS

The following list (by alphabetic order) corresponds to new goals found in the protocols used for the testing of the system.

Note:
1. Each goal name has the prefix CHECK attached to it e.g. check_temperature to distinguish from the other slots of the goal.
2. The definition of a goal describes what the physician will do or ask.

<table>
<thead>
<tr>
<th>SUBJECT / NAME OF A GOAL</th>
<th>DEFINITION OF A GOAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>5TH YEAR STUDENT</td>
<td></td>
</tr>
<tr>
<td>palpation_kidney</td>
<td>(palpate the kidney)</td>
</tr>
<tr>
<td>temperature</td>
<td>(ask if the patient has temperature)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>SENIOR HOUSE OFFICER</td>
<td></td>
</tr>
<tr>
<td>movements_back</td>
<td>(check a range of movements of the back)</td>
</tr>
<tr>
<td>pedal_movements</td>
<td>(check pedal pulses)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>CONSULTANT</td>
<td></td>
</tr>
<tr>
<td>blood_tests</td>
<td>(ask for blood test to be done)</td>
</tr>
<tr>
<td>cardio_vascular_examination</td>
<td>(do a cardio vascular examination)</td>
</tr>
<tr>
<td>chest_xrays</td>
<td>(ask for xrays of the chest to be done)</td>
</tr>
<tr>
<td>crp</td>
<td>ask for an CRP to be done - a specific blood test</td>
</tr>
<tr>
<td>esr</td>
<td>(ask for an ESR to be done - a specific blood test)</td>
</tr>
<tr>
<td>general_examination</td>
<td>(do a general physical examination)</td>
</tr>
<tr>
<td>pelvic_xrays</td>
<td>(ask for pelvic xrays to be done)</td>
</tr>
<tr>
<td>respiratory_examination</td>
<td>(do a respiratory examination)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>5TH YEAR STUDENT, GP-T and CONSULTANT</td>
<td></td>
</tr>
<tr>
<td>abdominal_examination</td>
<td>(examine the abdomen)</td>
</tr>
</tbody>
</table>
Sensation (check power during neurological examination)
Sensation (check sensation during neurological examination)
APPENDIX D3: LIST OF RENAMED GOALS

The following list corresponds to already existing goals found in the protocols used for the testing of the system and which have been given a different name. The format is : newname/oldname.

Note: Each goal name has the prefix CHECK attached to it e.g. check_movements_passive to distinguish from the other slots of the goal.

5TH YEAR STUDENT
movements_passive/flexion passive
movements_active/flexion active
lateral_flexion/rotation

SHO
movements_knees/ flexion_legs
movements_hips/ bending_back

5TH YEAR STUDENT and CONSULTANT
extension/bending_back
APPENDIX D4: INTERACTIONS OF STRATEGIES

This appendix contains examples of interactions of reasoning strategies at various levels of expertise that have been generated by the program during the testing phase.

1. Interactions of the 3rd year student

INTERACTION 3RD YEAR STUDENT
HGN SPEC - LEVEL 1 (same level)
STRATEGY: HGN
Goal: check_severity_pain_more
Observation/Action: ask_intermittent_pain
Hypothesis: pressure_introabdominal

List of hypotheses: list_hypotheses([pressure_introabdominal])

STRATEGY: SPEC
Goal: check_severity_pain_more
Hypothesis parent: pressure_introabdominal
Hypothesis child: problem_of_rectum
Evidence: [ask_intermittent_pain]

List of hypotheses:
list_hypotheses([problem_of_rectum, pressure_introabdominal])

STRATEGY: SPEC
Goal: check_severity_pain_more
Hypothesis parent: pressure_introabdominal
Hypothesis child: problem_of_bladder
Evidence: [ask_intermittent_pain]

List of hypotheses:
list_hypotheses([problem_of_bladder, problem_of_rectum, pressure_introabdominal])

STRATEGY: SPEC
Goal: check_severity_pain_more
Hypothesis parent: pressure_introabdominal
Hypothesis child: problem_of_stomach
Evidence: [ask_intermittent_pain]

List of hypotheses:
list_hypotheses([problem_of_stomach, problem_of_bladder, problem_of_rectum, pressure_introabdominal])

INTERACTION 3RD YEAR STUDENT
PREF HGN - LEVEL 1 (same level)
STRATEGY: PREF
Goal: check_similar_pain
Observation/Action: similar_pain
Observation refined to or Routine protocol used: refine_treatment_previous_pain

STRATEGY: HGN
Goal: check_similar_pain
Observation/Action: similar_pain
Hypothesis: recurring_problem

List of hypotheses: list_hypotheses([recurring_problem])

INTERACTION 3RD YEAR STUDENT
HGN ELIM - LEVEL 3 (higher level)
STRATEGY: HGN
Goal: check_episodic_continue_pain
Observation/Action: ask_gradual_episodic_pain
Hypothesis: muscle_strains

List of hypotheses: list_hypotheses([muscle_strains])

Differential Diagnosis: differential_diagnosis([muscle_strains])

STRATEGY: ELIM
Goal: check_episodic_continue_pain
Hypothesis ruled out: muscle_strains
Evidence: sudden_onset_continuous_pain
Differential Diagnosis: differential_diagnosis([])
2. Interactions of the 5th year student

INTERACTION 5TH YEAR STUDENT
HGN SPEC - LEVEL 1 (lower level)

STRATEGY: HGN
Goal: check_kidneys_problems
Observation/Action: no_left_kidney
Hypothesis: abnormality_of urinary tract

List of hypotheses: list_hypotheses([abnormality_of urinary tract])

STRATEGY: SPEC
Goal: check_kidneys_problems
Hypothesis parent: abnormality_of urinary tract
Hypothesis child: double_ureters
Evidence: [no_left_kidney]

List of hypotheses:
list_hypotheses([double_ureters, abnormality_of urinary tract])

STRATEGY: SPEC
Goal: check_kidneys_problems
Hypothesis parent: abnormality_of urinary tract
Hypothesis child: ectopic_ureters
Evidence: [no_left_kidney]

List of hypotheses: list_hypotheses([ectopic_ureters, double_ureters, abnormality_of urinary tract])

STRATEGY: SPEC
Goal: check_kidneys_problems
Hypothesis parent: abnormality_of urinary tract
Hypothesis child: kidney_material_lower_down
Evidence: [no_left_kidney]

List of hypotheses: list_hypotheses([kidney_material_lower_down, ectopic_ureters, double_ureters, abnormality_of urinary tract])
INTERACTION 5TH YEAR STUDENT
HGN ELIM - LEVEL 3 (same level)

STRATEGY: HGN
Goal: check_flexion_passive
Observation/Action: ask_pain_with_passive_movements
Hypothesis: rodicular_pain_problem

List of hypotheses: list_hypotheses([rodicular_pain_problem])

Differential Diagnosis: differential_diagnosis([rodicular_pain_problem])

STRATEGY: ELIM
Goal: check_flexion_passive
Hypothesis ruled out: rodicular_pain_problem
Evidence: no_pain_with_passive_movements
Differential Diagnosis: differential_diagnosis([])

INTERACTION 5TH YEAR STUDENT
HGN's - LEVEL 4 (higher level)

STRATEGY: HGN (repetition)
Goal: check_age
Observation: [over42_years_old, back_pain]
Hypothesis: breast_carcinoma

List of hypotheses: list_hypotheses([breast_carcinoma])

STRATEGY: HGN (repetition)
Goal: check_age
Observation: [over42_years_old, fertile_woman, back_pain]
Hypothesis: cholecystitis_disease

List of hypotheses:
list_hypotheses([cholecystitis_disease, breast_carcinoma])
3. Interactions of the Senior House Officer

INTERACTION SENIOR HOUSE OFFICER
HGN SPEC - LEVEL 1 (lower level)

STRATEGY: HGN
Goal: check_duration_pain
Observation/Action: ask_onset_pain_by_sho
Hypothesis: acute

List of hypotheses: list_hypotheses([acute])

STRATEGY: SPEC
Goal: check_duration_pain
Hypothesis parent: acute
Hypothesis child: muscle_strain
Evidence: [onset_pain_this_morning]

List of hypotheses: list_hypotheses([muscle_strain, acute])

STRATEGY: SPEC
Goal: check_duration_pain
Hypothesis parent: acute
Hypothesis child: slipped_disc
Evidence: [onset_pain_this_morning]

List of hypotheses: list_hypotheses([slipped_disc, muscle_strain, acute])

STRATEGY: SPEC
Goal: check_duration_pain
Hypothesis parent: acute
Hypothesis child: localized_trauma
Evidence: [onset_pain_this_morning]

List of hypotheses: list_hypotheses([localized_trauma, slipped_disc, muscle_strain, acute])

STRATEGY: HGN
Goal: check_duration_pain
Observation/Action: ask_onset_pain_by_sho
Hypothesis: chronic

List of hypotheses:
list_hypotheses([chronic, localized_trauma, slipped_disc, muscle_strain, acute])

STRATEGY: SPEC
Goal: check_duration_pain
Hypothesis parent: chronic
Hypothesis child: osteoarthritis
Evidence: [onset_pain_this_morning]

List of hypotheses:
list_hypotheses([osteoarthritis, chronic, localized_trauma, slipped_disc, muscle_strain, acute])

INTERACTION SENIOR HOUSE OFFICER
HGN ELIM SPEC - LEVEL 3 (lower level)
STRATEGY: HGN
Goal: check_pedal_movements
Observation/Action: ask_pulses_not_ok
Hypothesis: vascular_problem

List of hypotheses: list_hypotheses([vascular_problem])

Differential Diagnosis: differential_diagnosis([vascular_problem])

STRATEGY: ELIM
Goal: check_pedal_movements
Hypothesis ruled out: vascular_problem
Evidence: pulses_ok
Differential Diagnosis: differential_diagnosis([])

STRATEGY: HGN
Goal: check_pedal_movements
Observation/Action: ask_pedal_movements
Hypothesis: referred_pain_problem

List of hypotheses:
list_hypotheses([referred_pain_problem, vascular_problem])

Differential Diagnosis: differential_diagnosis([referred_pain_problem])

STRATEGY: ELIM
Goal: check_pedal_movements
Hypothesis ruled out: referred_pain_problem
Evidence: pulses_ok
Differential Diagnosis: differential_diagnosis([])

STRATEGY: SPEC
Goal: check_pedal_movements
Hypothesis parent: referred_pain_problem
Hypothesis child: arteriosclerosis
Evidence: ask_pulses_not_ok

List of hypotheses:
list_hypotheses([arteriosclerosis, referred_pain_problem, vascular_problem])

INTERACTION SENIOR HOUSE OFFICER
HGN CONF - LEVEL 5 (expected level)
STRATEGY: HGN
Goal: check_aggravating_factors
Observation/Action: no_aggravating_relieving_factors
Hypothesis: acute_problem

List of hypotheses: list_hypotheses([acute_problem])

STRATEGY: CONF
Goal: check_aggravating_factors
Hypothesis confirmed: acute_problem
Evidence: no_aggravating_relieving_factors
Differential Diagnosis: differential_diagnosis([acute_problem])
4. Interactions of the GP trainee

INTERACTION GP TRAINEE
PREF HGN - LEVEL 1 (lower level)

STRATEGY: PREF
Goal: check_aggravating_factors
Observation/Action: ask_aggravating_factors_by_gpt
Observation refined to or Routine protocol used: bony_pain

STRATEGY: HGN
Goal: check_aggravating_factors
Observation/Action: ask_aggravating_factors_by_gpt
Hypothesis: musculo_skeletal

List of hypotheses: list_hypotheses([musculo_skeletal])

INTERACTION GP TRAINEE
HGN SPEC - LEVEL 1 (lower level)

STRATEGY: HGN
Goal: check_check_current_waterwork_infection
Observation/Action: ask_current_waterwork_infection_by_gpt
Hypothesis: urinary_infection

List of hypotheses: list_hypotheses([urinary_infection, musculo_skeletal])

STRATEGY: SPEC
Goal: check_check_current_waterwork_infection
Hypothesis parent: urinary_infection
Hypothesis child: pyelonephritis
Evidence: [no_waterwork_infection_now]

List of hypotheses: list_hypotheses([pyelonephritis, urinary_infection, musculo_skeletal])

STRATEGY: SPEC
Goal: check_check_current_waterwork_infection
Hypothesis parent: urinary_infection
Hypothesis child: urinary_tract_infection
Evidence: [no_waterwork_infection_now]

List of hypotheses:
list_hypotheses([urinary_tract_infection,pyelonephritis,urinary_infection, musculo_skeletal])

INTERACTION GP TRAINEE
HGN ELIM - LEVEL 3 (lower level)
STRATEGY: HGN
Goal: check_waterwork_infections_problems
Observation/Action: ask_symptoms_of_urinary_infections
Hypothesis: urinary_infections

List of hypotheses: list_hypotheses([urinary_infections])

Differential Diagnosis: differential_diagnosis([urinary_infections])

STRATEGY: ELIM
Goal: check_waterwork_infections_problems
Hypothesis ruled out: urinary_infections
Evidence: no_symptoms_of_urinary_infections
Differential Diagnosis: differential_diagnosis([])

INTERACTION GP TRAINEE
PREF's - LEVEL 4 (lower level)
STRATEGY: PREF
Goal: check_relieving_factors
Observation/Action: lay_down_does_not_make_the_pain_better
Observation refined to or Routine protocol used: refine_nature_of_the_pain

STRATEGY: PREF (repetition)
Goal: check_relieving_factors
Observation: refine_nature_of_the_pain
Observation refined to or Routine protocol used: dull_nagging_pain

INTERACTION GP TRAINEE
HGN CONF - LEVEL 5 (expected level)

STRATEGY: HGN
Goal: check_back_pain_history
Observation/Action:
[location_pain, onset_pain, history_previous_back_pain]
Hypothesis: disc_problem

List of hypotheses: list_hypotheses([disc_problem])

STRATEGY: CONF
Goal: check_back_pain_history
Hypothesis confirmed: disc_problem
Evidence: back_pain_history
Differential Diagnosis: differential_diagnosis([disc_problem])

5. Interactions of the consultant

INTERACTION CONSULTANT
HGN PREF - LEVEL 1 (lower level)

STRATEGY: PREF
Goal: check_slr
Observation/Action: ask_slr_by_expert
Observation refined to or Routine protocol used: refine_irritation_nerve_root

STRATEGY: HGN
Goal: check_slr
Observation/Action: ask_irritation_nerve_root
Hypothesis: disc_problem

List of hypotheses: list_hypotheses([disc_problem])

INTERACTION CONSULTANT
HGN ELIM - LEVEL 3 (lower level)

STRATEGY: HGN
Goal: check_similar_pain_more
Observation/Action: ask_similar_pain_with_kidney_infection
Hypothesis: kidney_problem

List of hypotheses: list_hypotheses([kidney_problem])

Differential Diagnosis: differential_diagnosis([kidney_problem])

STRATEGY: ELIM
Goal: check_similar_pain_more
Hypothesis ruled out: kidney_problem
Evidence: dissimilar_current_pain_and_with_waterwork_infection
Differential Diagnosis: differential_diagnosis([])

INTERACTION CONSULTANT
HGN SPEC CONF ELIM - LEVEL 3 (lower level)

STRATEGY: HGN
Goal: check_history
Observation/Action: [history_back_pain, age_forties]
Hypothesis: degenerative_problem

List of hypotheses:
list_hypotheses([degenerative_problem, kidney_problem])

STRATEGY: SPEC
Goal: check_history
Hypothesis parent: degenerative_problem
Hypothesis child: problem_of_tear_in_anulous_of_disc
Evidence: [history_back_pain, age_forties]

List of hypotheses:
list_hypotheses([problem_of_tear_in_anulous_of_disc, degenerative_problem, kidney_problem])

STRATEGY: CONF
Goal: check_history
Hypothesis confirmed: problem_of_tear_in_anulous_of_disc
Evidence: history_patient
Differential Diagnosis:
differential_diagnosis([problem_of_tear_in_anulous_of_disc])
STRATEGY: ELIM
Goal: check_history
Hypothesis ruled out: problem_of_tear_in_anulous_of_disc
Evidence: history_of_patient
Differential Diagnosis: differential_diagnosis([])

INTERACTION CONSULTANT
HGN's - LEVEL 4 (lower level)
STRATEGY: HGN (repetition)
Goal: check_similar_pain
Observation: [pain_is_similar, past_epidoses_of_backpain]
Hypothesis: slipped_disc_with_true_sciatica

List of hypotheses: list_hypotheses([slipped_disc_with_true_sciatica])

INTERACTION CONSULTANT
HGN CONF - LEVEL 5 (expected level)
STRATEGY: HGN
Goal: check_radiation_previous_pain_more
Observation/Action: ask_more_radiation_previous_pain
Hypothesis: previous_prolapsed_intervertebral_disc

List of hypotheses:
list_hypotheses([previous_prolapsed_intervertebral_disc])

STRATEGY: CONF
Goal: check_radiation_previous_pain_more
Hypothesis confirmed: previous_prolapsed_intervertebral_disc
Evidence: ask_previous_sciatic_pain
Differential Diagnosis:

differential_diagnosis([previous_prolapsed_intervertebral_disc])
APPENDIX E: MEDICAL GLOSSARY

Differential diagnosis: a list of hypotheses that the physician is considering as a possible solution to the diagnostic problem.

Finding: see observation

Hypothesis: a disease or a more general disease category that the physician has generated. In the thesis, any problem that the physician thinks is the cause of the patient's pain (e.g., inflammatory problem) will also be considered as a hypothesis.

Medical problem solving: refers to the physician solving her or his own diagnostic problem. In this thesis, the following terms (medical reasoning, medical diagnostic process, clinical reasoning) have the same meaning as medical problem solving.

Observation: a medical fact about a patient which can be viewed as the direct evidence from which hypotheses about possible diagnoses are generated and tested. This evidence can be either a sign, symptom, or a test result. (As is explained in chapter eight, physicians interviewed in the main study made a distinction between observations which belong to the patient and observations that are generated by the physician but which are not specific to the patient).

Patient case (also referred to as patient's problem) contains the initial complaint of the patient.

Routine protocol: a routine format of a medical record (e.g., social history) that serves the function of a guide to novice physicians for collecting information.

Sign: objective and observable by the physician

Symptom: subjective sensation reported by the patient or any observation that the patient gives to the physician.