All systems of medicine hope to make the sick better and prevent people from becoming sick. To do so, all practising physicians (whether they subscribe to the tenets of modern medicine, naturopathy, ayurveda, homeopathy or osteopathy) intervene at different levels of the illness process. Such interventions are based on particular explanatory models of what caused the illness in the first place. Treatments prescribed by different systems of medicine differ because the explanatory models used also differ. Systems of medicine can be broadly categorized into “gnostic” and “epistemic.” In the first category, emphasis is placed on the knower; in the second, on what is known. Although such distinctions are, of course, entirely artificial, modern medicine, often wrongly termed “allopathy,” is regarded as primarily epistemic, since what is known is believed to transcend the particularities of the knower. The basis of this confidence lies in our faith that the ways of gathering knowledge (the “scientific” method) best reflect reality. Modern medicine is believed to rest on a firm scientific basis.

As facts accumulated, it became impossible for anyone to master the information gathered. Disciplines came into being, each characterized by practitioners who shared specific interests, particular skills and instruments. The disciplinary matrix served to provide cohesion and commonalities that fostered more rapid accumulation of information in selected domains. Newer disciplines and sub-disciplines emerged as older disciplines entered edges of incomprehensibility. Physics and biology provided the basis for physiology and biophysics, biology and chemistry spawned biochemistry, which, in turn, generated molecular biology. These, along with anatomy, came to represent the basic biomedical sciences. It was felt that a proper understanding of these sciences would provide a firm basis for the proper practice of medicine.

It may, however, be quite simplistic to consider the

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WHERE WE WANT TO BE BY 2010

“Give us good measure”: the basic medical sciences and the overloaded curriculum
individual patient as being comprised only of molecules, cells, tissues and organs (the domains of study of the basic biomedical sciences). The patient forms part of a social network that may have a greater impact on what makes a person a patient and what makes the patient well (Fig. 1). Thus, Feinstein has argued cogently that one should consider 2 sorts of basic biomedical sciences — the explanatory (or explicatory) and the interventionist. The first seeks answers to questions such as, “How does nature work? What are the underlying mechanisms?” The interventionist basic sciences seek answers to the query, “How do we change what nature has done or thwart what it might do?” Feinstein argues that excessive attention has been paid to the explicatory basic sciences, leading to an imbalance in the training of physicians.

A conceptual framework that seeks to include both aspects is shown in Fig. 2. This is a variation of the “iterative loop” originally developed for epidemiological analysis by Tugwell and others. This de-jargoned version was developed for the McMaster MD undergraduate program by Pickering, Neufeld and Rangachari.

This approach can be modified to focus on any of the disciplines that form part of the medical sciences. Consider, for instance, the teaching of pharmacology. The essential elements of pharmacology can be neatly incorporated into the aphorism “drug meets body; body meets drug.” What the drug does to the body forms the domain of pharmacodynamics, and what the body does to the drug is the realm of pharmacokinetics. The principles of pharmacology can be better appreciated by medical students when placed in a clinical context. Fig. 3 shows a scheme that considers the essential elements of pharmacology and therapeutics as applied to clinical situations.

The abstract nature of this model can be better appreciated with a worked clinical example, in which each of the questions can be framed separately. Fig. 4 shows the case of acute angle glaucoma and the detailed consideration of a single drug, timolol acetate.

Let us consider in greater detail the section termed “Mechanism of Action.” The student who wishes to appreciate this component needs to have a working knowledge of several elements, such as adrenoreceptors, ciliary epithelium, sympathetic stimulation and aqueous humour formation. Each of these, in turn, requires an appreciation of other elements. Thus, a proper appreciation of adrenoreceptors would require an understanding of drug–receptor interactions, which, in turn, necessitates a comprehension of the principles of equilibria and the Law of Mass Action. Similarly, to understand the production of aqueous humour, the student would need to understand at the barest minimum not only the functioning of cell membranes and epithe-

![Fig. 1: Model of the patient's place in a biomedical context and as part of a social network.](image-url)
lial physiology but also, in a more general sense, the principles relating water to solute transport. Presented in this fashion, the accumulated information required to deal with even one drug for one clinical condition appears overwhelming. Little wonder, then, that teachers and students despair of dealing with a burgeoning curriculum. To provide the students with a comprehensive basis for dealing with all possible problems is clearly unworkable.

One possible approach is to create a “bare-bones learning agenda.” I produced one such document for the MD undergraduate program at McMaster University. I prepared a list of items dealing with the biological sciences that I regarded as essential. The items of information listed were so basic and general that a lack of awareness or appreciation would pro-

Fig. 2: Conceptual model that includes both explanatory (explicative) and interventionist biomedical sciences. The model is a variation of the iterative loop developed for epidemiological analysis.
duce a physician who would be an embarrassment to the program. In framing such a list, I used a mini-Delphi approach, in which I met individually with experts in several disciplines and generated a list, which I refined and fed back to them.

This “non-embarrassing,” “bare-bones” or “non-negotiable learning agenda” would serve as a framework for either a lecture-based or problem-based curriculum. In the latter instance, these items would provide the substrate for the writing of problems, using carefully selected clinical situations that have heuristic and practical value.

The document prepared emphasized that students needed a proper understanding of physicochemical principles, as both physiology and, by extension, pathophysiology are the application of the general principles of physics and chemistry to living organisms. Particular emphasis was needed to ensure that they had a clear understanding of the relations between extensive and corresponding intensive variables so that they could appreciate the crucial relationships between flows and conjugate driving forces; the Law of Mass Action, Le Chatelier’s principle; an operational acquaintance with thermodynamics; and the notions of equilibria and steady state. It is interesting that, in the example given above of timolol, an understanding of drug–receptor interactions would require an understanding of the Law of Mass Action, and an understanding of the formation of aqueous humour would necessitate an understanding of the relations between flows of solute/water and their conjugate driving forces.

It is worth emphasizing that appreciation of and grounding in physicochemical principles also requires a deeper appreciation of scientific reasoning and methodology. The approach used by the proponents

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![Diagram](image-url)

Fig. 3: Essential elements of pharmacology and therapeutics as applied to clinical situations.
Clinical Problem: Open Angle Glaucoma

Therapeutic Goals:
- To control progressive visual loss / preserve structure and function of optic nerve / eliminate pain and improve vision in acute forms
- Achieved by reducing intra-ocular pressure (IOP)

Options:
- Drugs
- Lasers and/or surgery

Biological rationale:
- Decrease formation of aqueous humour
- Increase trabecular outflow

Drugs available:
- β blockers
- adrenergic agonists
- cholinergic agonists
- carbonic anhydrase inhibitors
- prostaglandin analogs

Worked example:

Drug: Timolol maleate

Class: β blocker (non-selective)

Mechanism of Action: Blocks adrenergic receptors on the ciliary epithelium, reduces effects of sympathetic stimulation, reduces aqueous humour formation leading to a fall in IOP

Route of administration: Topical

Formulations: Solution; gel

Kinetic data: Can be absorbed systemically; hepatic biotransformation by-passed.

Adverse effects: Systemic effects after absorption. Predictable based on non-selective β blocking effects. Bronchospasm, exaggeration of congestive heart failure, cardiac arrythmias, systemic hypotension, syncope, etc.

Caution: with underlying cardiac, pulmonary conditions. Proper techniques need to be taught.

Advantages: Forgiving drug; accumulates in tissues; effects persist 2 to 4 weeks after withdrawal; added effects when used with a miotic.

Effectiveness clinically: Lowered IOP linked to reduced incidence of glaucomatous damage to visual fields.

Fig. 4: Model of the principles of pharmacology: clinical problem and worked example.
of the New Learning (mentioned earlier) was essentially reductionistic. That term has become a term of abuse these days, and the spectre of holism looms large in the minds of our students. There are, as Schultz’ emphasizes, several different levels of reductionism. Constitutive reductionism implies that inanimate and animate matter are governed by the same physicochemical laws. Explanatory reductionism is the belief that a whole may be represented as a function (mathematically speaking) of its constituent parts. To paraphrase Schultz, this suggests that one could predict or “understand” the properties of the whole if one knows the properties of “all” of the parts and the mathematical functions relating them. This goes beyond a simple additive/linear relationship and acknowledges the existence of what have come to be called “emergent” properties. Operational reductionism is the belief that the properties or behaviour of a composite system can be predicted from an understanding of the properties of constituent parts studied in isolation. The triumphs of molecular biology have given new life to this level of reductionism, although physiologists would caution that any analysis must permit the development of emergent properties. Although reductive analysis has been one of the most successful strategies ever developed for exploring the universe, one must build into the analysis the potential for non-linear behaviour. The appropriate response to the limitations of reductionism is not mysticism.

This point cannot be overemphasized. The temper of the times is disturbingly anti-scientific. We must ensure that our students acquire a deeper respect for the processes of science. The reflex response to what are seen as the perils of reductionism is not to embrace mysticism and non-rationality. The spectacular success of modern science must not blind us to its shortcomings. Equally undue emphasis on some of those pitfalls must not eliminate our deeper appreciation of how much that approach has made possible. The foundation of all the basic sciences is the demonstrated success of rationalism. If we permit “that capability and God-like reason to fust in us unus’d” (as Shakespeare said in Hamlet), we would be negating the past and mortgaging the future.

References


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