discusses the hadronic mass spectrum. Current numerical simulation results are sketched, but the bulk of the discussion is devoted to attempts to extract masses and coupling constants of light hadrons from QCD sum rules and the operator product expansion. The equilibrium behavior of QCD at nonzero temperature or density is the topic of the next quarter. This covers the possible stability of quark matter, high-temperature dynamics of quark–gluon plasma, and the current understanding of finite-temperature phase transitions.

The last quarter of the book is largely devoted to heavy-ion collisions. The focus here is on possible collective phenomena in high-energy collisions and on the prospects for observing such phenomena in upcoming experiments. Naturally the material in this section is much more speculative than in the preceding material. Shuryak argues rather plausibly that heavy-ion collisions may actually be able to tell us something useful about the QCD vacuum structure.

The wide scope should make this book stimulating reading for almost anyone interested in nonperturbative QCD. Unfortunately, the level of detail varies tremendously from section to section. Many topics are presented in such a sketchy fashion that readers who are not already familiar with the material will likely find it hard to appreciate the significance or reliability of the quoted calculations. Surprisingly little emphasis is placed on some important subjects, such as nonperturbative renormalization-group flows, while other areas (like sum-rule-based phenomenology) receive a disproportionately large share of attention. These flaws are partially compensated by the unusually comprehensive and well-organized bibliography. (In fact, for some people the bibliography alone may justify purchasing the book.)

This book desperately needed—and failed to receive—the attention of a good technical editor. Misprints, awkward sentences and undefined symbols abound. Numerous hand-drawn graphs have inadequate captions and are difficult to interpret.

Shuryak conveys a tremendous sense of enthusiasm and optimism about the progress in understanding QCD (so much so that at times he is insufficiently critical of some of the work he quotes). He argues convincingly that QCD has not yet been reduced to a mere "calculational" problem; rather, there remains a clear need for improved insight and better physical understanding of its dynamics. Despite the book's drawbacks, I would recommend it as a good starting place for anyone interested in learning about nonperturbative QCD.

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From Clocks to Chaos: The Rhythms of Life

Leon Glass and Michael C. Mackey
Princeton U. P., Princeton, N. J., 1988. 248 pp.
$45.00 hc ISBN 0-691-08495-5; $13.95 pb ISBN 0-691-08496-3

During the past 15 years or so, the theory of dynamical systems in general, and of their chaotic behavior in particular, has become one of the areas at the forefront of research in mathematical physics. In theoretical research, in experiments or in both, chaotic behavior has been discovered to occur in a number of phenomena where it was more or less expected: in fluid dynamics—including the dripping of a faucet—in chemical reactions, in the propagation of laser light and in celestial dynamics. In some other areas, such as the stock market and the subject matter of this book, physiology, the applications are perhaps less obvious.

The authors are a theoretical physicist turned physiologist (Glass) and a physiologist (Mackey), both of whom have made substantial contributions to the application of the theory of dynamical systems to the analysis of physiological phenomena. Thus, as one would expect, their book is an authoritative reference. Among the mathematical concepts they explain and apply to physiological phenomena are limit cycles, attractors, various types of bifurcations (with emphasis on sub- and supercritical Hopf bifurcations and the period-doubling cascade), chaotic behavior, Hausdorff dimension, the Liaponov exponent, feedback (positive and negative), phase locking and wave propagation. The phenomena analyzed include fibrillation, mitosis, leukemia survival, migraine headaches, jet lag, neural networks, respiratory and sleep arrhythmia, orgasm and considerably more topics.

Each chapter concludes with a summary and a valuable set of notes and references allowing the reader to use the text materials as a departure for further study. There are also an extensive 30-page bibliography and a mathematical appendix, which gives some details of dynamical systems theory to help the reader in understanding the text.

However, the book is not entirely satisfactory. If it is addressed to physiologists the physical and mathematical content is too skimpy, while if it is addressed to physicists the material on physiology is presented much too schematically. As an example of the former deficiency, the authors describe a linear stability analysis of a system of differential equations without explaining the Taylor-series origin of the matrix of derivatives. Another example is the several discussions of Hopf bifurcation at different locations in the book, which make use of phase diagrams, differential equations and finite-difference equations, respectively. The authors make no attempt to explain the connections or the differences among the various concepts; for example, they write that a steady state is stable if all eigenvalues lie within the unit circle, without explaining why. In chapter 2 the period-doubling bifurcations are discussed with detailed explanations and diagrams; nonetheless I do not believe that an individual being introduced to the subject could gain any sort of working knowledge of it from this presentation. There are other examples, but these should suffice. Also, as a person not trained or knowledgeable in physiology, I was hard pressed to figure out the basic ideas from the abbreviated descriptions presented.

My conclusion is that this book would not be a useful text, but that it contains a wealth of information that would be very useful as a starting point for physicists or mathematicians interested in applying dynamical systems ideas to physiology problems. It would be less useful to physiologists, who might be better advised to begin with a more elementary, but more detailed, description of the mathematical ideas involved.

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Matched Asymptotic Expansions: Ideas and Techniques

P. A. Lagerstrom
Springer-Verlag, New York, 1988. 250 pp.
$39.95 hc ISBN 0-387-96811-3

I am critical of courses that claim to teach mathematical methods of physics but emphasize only problems that have closed-form analytical solutions. One often begins research in physics by formulating a model and then making simplifying assumptions to

Laser Forefront

A Monthly Update on the State of Technology in the Laser Industry

In the News:

Wavelength-selective mirrors enhance ion laser performance

Introduced at CLEO/QELS '89, these specially coated output couplers allow single-line operation without an intracavity prism. They are especially effective in single-frequency applications, where elimination of the prism and its thermal compensation scheme improves both power stability and frequency stability. Mirrors are available for 514.5, 488.0, 363.8, or 351.1 nm operation.

Technology Notes:

Gaussian-coupled resonators improve the speed and accuracy of experimental results

In the design of high-energy pulsed Nd:YAG lasers, there has always been a trade-off between maximum output energy and single transverse mode operation. For instance, if a pure TEM_{00} Gaussian mode is extracted from a typical oscillator/amplifier laser with 7-mm rods, output energies of only a few hundred millijoules can be achieved. However, by allowing admixtures of higher-order transverse modes, energies of about 1 J can be obtained.

In the diffraction-coupled resonator that Quanta-Ray® introduced in 1979, high output energies were achieved in a single transverse mode. However, the beam profile of those lasers exhibited a characteristic donut shape that is undesirable for a large number of experiments.

Recently, it has become technically possible to produce output couplers on which the reflectivity varies as a function of the radial position on the mirror. If this variation has a Gaussian profile, large mode volumes can be sustained in the oscillator with excellent discrimination against higher-order transverse modes. As a consequence, output energies of about 1 J can now be obtained with a smooth spatial profile.

The reflectivity of such a mirror can be described as follows:

$R(r) = R_{max} \exp[-2(r/w)^c]$,

where c equals 2 for Gaussian reflectivity and 3 for super-Gaussian.

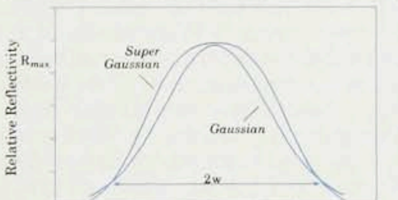

Figure 1. Gaussian and super-Gaussian reflectivities

By adjusting the maximum reflectivity (R_{max}), the width (w), and the order of the Gaussian (c), the output energy for a given oscillator design with a specific magnification can be optimized, while maintaining a smooth output beam profile.

At Spectra-Physics, special techniques have been developed to make possible Gaussian reflectivity coatings that closely match this ideal theoretical curve.

Gaussian reflective optics were incorporated in the new Quanta-Ray® line of GCR (Gaussian Coupled Resonator) Nd:YAG lasers, which produce high-energy output beams with smooth spatial profiles. Since these lasers operate in a single transverse mode, they can also be injection seeded to produce a single longitudinal mode.

The high-quality spatial profile of the new GCR lasers has resulted in much higher harmonic conversion efficiencies. Dye laser conversion efficiencies also have improved substantially.

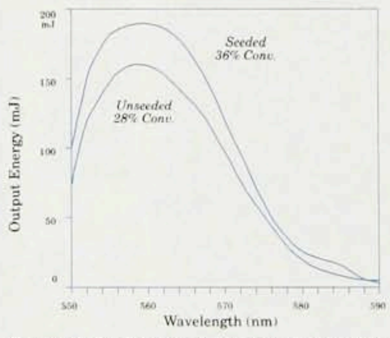

Figure 2. Performance characteristics of the GCR-4-10 and the PDL-3 pulsed dye laser

For the user, the new GCR means better beam definition in both space and time, for faster and more accurate experimental results.

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isolate a well-defined mathematical problem, often in the form of a differential equation. An ill-trained researcher may be dismayed to learn that this equation is not discussed in Milton Abramowitz and Irene Segun's *Handbook of Mathematical Functions* (Dover, New York, 1965). For those who have taken typical courses on mathematical methods of physics there is then apparently nothing to do but to spend weeks or months away from the original physics problem, writing and debugging computer code, sifting through copious numerical output, and generating masses of scrap paper.

It is important that students be made aware of the arsenal of techniques for obtaining approximate solutions to problems that are too difficult to solve in closed form. Such techniques are referred to as asymptotic methods. Rather than obscuring the interesting qualitative features of a physical problem, asymptotic techniques often isolate and magnify the most salient physical content of the model. For example, a WKB approximation makes evident the wave-like behavior of a particle in a classically allowed region; boundary-layer theory delineates the abrupt variations that can occur in physical media over very narrow regions. Asymptotic methods often tell us whether the original model is physically realistic. One should postpone numerical studies until the qualitative features of a problem's solution are well understood.

The method of matched asymptotic expansions is the key idea behind most approximation methods. It lies at the core of WKB theory and boundary-layer theory. Unfortunately, it is not easy to teach asymptotic methods, and it is even more difficult to write about them. They are difficult, and sometimes impossible, to justify in rigorous terms. Examples have to be chosen wisely; they must be sufficiently nontrivial that exact solutions are not available, and yet simple enough that a student can learn without getting lost in details. It is only through the study of many examples that a student can develop the intuition needed to attack a tough problem.

Paco Lagerstrom's *Matched Asymptotic Expansions* has dozens of rich examples, which are well explained, well organized and chosen from diverse scientific disciplines. One can find a discussion of the differential equation describing a spherical self-gravitating gas cloud as well as of the differential equation describing the shape of a meniscus.

Lagerstrom's book is organized into three sections: a brief introduction, a 150-page collection of examples using ordinary differential equations and a relatively short discussion of partial differential equations. The style of writing throughout is rather dry and formal, but once past the introduction, the author warms up to the discussion of his examples, which he has evidently been amassing for a lifetime. There are exercises, but no solutions.

There is, however, no dramatic evidence in the book that would convince a novice that asymptotic methods are powerful. Graphs comparing asymptotic approximations with exact solutions would have helped immeasurably. For example, even if one can show that the error is of order ϵ^2, this does not necessarily mean that if $\epsilon = 0.1$, the exact solution and the asymptotic approximation differ by 1%. Comparison plots would demonstrate to the potential user the impressive and often unexpected numerical accuracy of asymptotic approximations.

Asymptotic analysis almost always gives rise to divergent series, but there is no discussion of summation theory in the book. The justification for undertaking asymptotic approximations is that one can sum the resulting divergent series to obtain a sequence of approximants that converge to the exact answer. A book on asymptotics ought to dwell on this point.

Finally, this book should have had a more detailed index.

Despite these shortcomings, *Matched Asymptotic Expansions* would be a useful book for anyone teaching a course on mathematical methods of physics.

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Astrophysics of the Sun

Harold Zirin
Cambridge U. P., New York, 1988. 433 pp. $49.50 hc ISBN 0-521-30268-4; $22.95 pb ISBN 0-521-31607-3

Astrophysics of the Sun by Harold Zirin gives an interesting account of our knowledge of the Sun from an observer's point of view. That knowledge has increased dramatically in the past 30 years through the development of new instrumentation and the capability of observing from space. The Sun can now be observed in electromagnetic radiation at wavelengths ranging impressively from radio down to gamma rays, revealing the Sun to be a natural laboratory