DOE CSGF

Application

Name: Carl Boettiger

Student Data

First name	*Middle name*	*Last name*
Carl		**Boettiger**

[redacted]

Academic Status

Current Academic Status:	**Graduate student**
If Other (please specify):	
Number of years in a doctoral program:	**0**

Current College/University

University
University of California, Davis

Department	*Academic Discipline*
Population Biology	**Biology –– Ecology & Evolution**

Citizenship

Country of Birth: **USA**

U.S. Citizen: **Yes**

If no,

- *Country of Citizenship:*
- *Permanent Resident Alien:* -----

  If yes,
  - *PRA Number:*
  - *Port of Entry:*

Name: Carl Boettiger

Graduate Advisor

The graduate advisor is the person from the preferred institution **who views and approves the Program of Study.**

First Name	*Last Name*
Alan	**Hastings**
Institution	*Title (Dr., Ms., Professor, ...)*
University of California, Davis	**Professor**

[redacted]

Name: Carl Boettiger

Grade Point Average

Please normalize to 4.0.

Undergraduate Cumulative GPA: **3.6**

Graduate Cumulative GPA: **4.0**

Current University

Institution	*Date Started*	*Major*	*Degree*	*Date Degree Expected*	*GPA*
University of California, Davis	September 2007	Population Biology	Ph.D	June 2012	4.0

Previous Universities and Colleges (Begin with the most recent institution)

Institution	*Dates Attended*	*Major*	*Degree*	*Date Degree Received*	*GPA*
Princeton University	Sept 2003 – June 2007	Physics	AB	06/03/2007	3.6

University Preference

University or Universities you plan to attend if awarded a fellowship. The student's department must certify that it will not impose support activities (e.g. teaching, grading, etc.) upon the fellow for the duration of the fellowship. If you plan to remain at your current school, please list it here. **If, after submitting this application, you change your preferred university, please notify the DOE CSGF office immediately.**

University Preference	*Academic Discipline*	*Topic of Interest*
University of California, Davis	Population Biology	Mathematical Population Biology

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Graduate Record Examination

Verification of these scores is required. (Note: Official Graduate Record Examination (GRE) Scores must be sent directly by the Educational Testing Service to Krell Institute/DOE Computational Science Graduate Fellowship program. Krell Institute's Institution Code is **6343**)

Your name as it appears on your GRE record: **Carl D Boettiger**

Date test taken/to be taken: **11/07/2006**

GRE Test Results

			Reported from ETS	
Examination	***Score***	***Percentile(%)***	***Score***	***Percentile(%)***
Verbal	620	88	620	89
Quantitative	790	91	790	92
Analytical or Analytical Writing	6	96	6.0	96

References

List at least three persons familiar with your academic preparation and your technical abilities. Please have these individuals mail the reference forms directly to Krell Institute.

	Title	*First name*	*Last name*	*Institution*	*E–mail*	*Status*
1.	**Professor**	**Alan**	**Hastings**	**University of California, Davis**	[redacted]	**Submitted**
2.	**Professor**	**Joshua**	**Weitz**	**Georgia Institute of Technology**		**Submitted**
3.	**Professor**	**Stephen**	**Pacala**	**Princeton University**		**Submitted**
4.	**Professor**	**Simon**	**Levin**	**Princeton University**		**Submitted**

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Federal Lab/Industry Lab Experience

Begin with current or most recent Lab. Please include employer, dates, position, and nature of work.

Other Employment

Begin with current or most recent employment. Please include employer, dates employment started and ended, position, and nature of work.

1) Princeton Physics Dept and Ecology and Evolution Dept. 9/2006–6/2007. Researcher. Forest modeling.
2) Princeton Princeton Plasma Physics Institute. 6/2006–8/2006. Research Fellow. Developed novel genetic algorithm for solving boundary value problems.
3) Princeton Physics Dept and Ecology and Evolution Dept. 1/2006–6/2006 Researcher, evolutionary dynamics theory.
4) Princeton Physics Dept 9/2005–1/2006 Researcher. Clonal interference in Bacterial Evolution.
5) Princeton Geology Dept 6/2005–8/2005 Sequencing and phylogenetic analysis of extremophilic bacteria.
6) Princeton Astrophysics Dept 6/2004–8/2004. Research assistant, analysis of large–scale structure of the universe.

Academic Awards and Honors

Include undergraduate and graduate honors (if applicable).

1) Elected to Membership in the Society of Sigma Xi, 2007
2) Allen G. Shenstone Prize, Princeton Physics Dept, 2007
3) Class of 1870 Old English Prize, Princeton, 2007
4) Kusaka Memorial Prize, Princeton Physics Dept, 2006
5) Plasma Physics Fellow, Princeton Plasma Physics Lab, 2006

Extracurricular Activities

Include technical societies and service organizations.

1) Sacramento Inner City Outings volunteer, Sierra Club, 2007––current
2) Volunteer Coach, Odyssey of the Mind, 2005–2006
3) Science Olympiad Judge, New Jersey State competition, 2007
4) Outdoor Action Leader Trainer Chair, 2006–2007
5) Outdoor Action Leader Trainer, 2005–2007
6) Outdoor Action Orientation Leader, 2004–2007
7) Climbing wall Instructor, 2004–2007
8) Climbing wall Coordinator 2006–2007

9) Wilderness First Aid Instructor, 2004–2007
10) Residential College Peer Advisor, 2006–2007
11) Physics Society, 2003–2007

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Research Statements

This information is vital to the overall evaluation of your application.

1. Field of Interest

"Computational science" involves the innovative and essential use of high–performance computation, and/or the development of computational technologies, to advance knowledge or capabilities in a scientific or engineering discipline. Please describe (in no more than 300 words) how computational science will spur advances in your particular area of scientific or engineering interest. Reserve discussion of your specific thesis research for later essays.

Ecology concerns itself with the study of the interactions of diverse individuals in spatially heterogeneous environments. These interactions are characteristically nonlinear, heterogeneous environments require explicitly spatial models, while variable environmental conditions and finite population sizes require probabilistic interpretation. Because not all individuals are identical populations must often be subdivided into age or stage structures. Because ecological communities are open systems, they need not be at equilibrium. Transient, nonlinear, spatial, stochastic and structured models are all notoriously intractable by analytic methods. Meanwhile, research continues to emphasize the importance of these complications –– without which models may fail to reproduce essential elements such as the coexistence of species or the stability of a population.

In the face of such complexity, computational methods are often the only way to capture the richness of these systems. The rise in computational power continues to allow researchers to include these features more effectively. Because they are cast in the form of algorithmic rules rather than mathematical abstractions, they are more accessible to many ecologists. They more faithfully describe the natural system than the assumptions usually required by analytic methods, and more faithfully reproduce natural phenomena as a consequence of the importance of those details.

Accurate models not only improve our understanding of ecological systems and the component elements that give rise to their behavior, but also play a crucial role in policy decisions. Management of natural resource populations such as fisheries and forests; managing outbreaks of infectious diseases and identifying high–risk species for conservation efforts all require accurate models. These efforts are becoming increasingly global in scale, and larger populations, spatial area require increased computational power. These same challenges of transient, nonlinear, spatial and stochastic systems arise in fields from astrophysics to economics, and methods developed in one field continue to fuel advances in related fields.

2. Program of Study

The fellowship program of study requirement is designed to give you a breadth of competency in fields outside your own that will enhance your ability to perform computational science research. Please describe (in no more than 300 words) how you expect that the courses listed in your planned program of study outside your chosen discipline will contribute to your own research in the future.

My program of study in mathematics and computer science provides a crucial pillar for my research in ecology. A strong quantitative and computational foundation is crucial for successful research in theoretical ecology, a process I have already begun with my bachelor's degree in Physics. The courses in my program of study will build and expand upon my quantitative skills in two areas most important for my research into ecology: large–scale computing and stochastic processes.

In computer science, the course design and analysis of algorithms will not only help me construct more efficient and realistic simulations of ecological processes in the future, but also provide me with a common language and skills allowing me to bridge the gap to communicate with investigators of all disciplines who rely on large–scale scientific computation. Large scale scientific computation will help me with the integration of large data sets, estimating errors and addressing other common challenges posed by natural systems and real data. Parallel Algorithms will help me take advantage of the many aspects of ecological computation are particularly amenable to parallel computing,such as multiple realizations of a stochastic process or exploring the dynamics of a system throughout the very large parameter spaces typical in ecology.

In mathematics, asymptotic analysis is often used to provide a crucial analytic check on simulation results to ensure the exhibit the appropriate behavior under limiting cases. Asymptotic methods build nicely on my physics training but are perpetually underutilized in ecological models. I will take two quarters of stochastic dynamics, as both accurate model design and interpretation of stochastic simulation results require the tools (i.e. stationary processes, Markov chains) and intuition developed here.

3. High–Performance Computation and Research

One of the major sources of supercomputer time to support scientific research and discovery is the DOE's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program. INCITE designates large chunks of supercomputer time and data storage space – as much as 18.2 million supercomputer processor–hours total and hundreds of terabytes of disc space – for computationally intensive, large–scale research projects. It is not designed to merely shorten the time for a simulation or experiment. Rather, researchers use the supercomputer resources to conduct novel and highly detailed simulations of physical, chemical and biological structures and phenomena. The program provides the cycles necessary to produce major discoveries in a broad range of fields.

Successful INCITE projects in the past have included detailed simulations of:

- Exploding stars.
- Fluid turbulence and combustion.
- The interaction of turbulence on ion and electron spatial and temporal scales, important to the future of fusion energy.
- Fracture, fragmentation and strain, important to understand how materials behave under stress.

• Protein structure at the atomic level.

Information about machines used in the INCITE program can be found at: http://hpc.science.doe.gov/allocations/management/resources/viewAllAllocationPools.do.

In 300 words or less, outline how you would make a case for access to high performance computing through a program like INCITE in order to impact your own research.

I propose to explore the impact of colored environmental noise on population dynamics. Because both populations and their environment are inherently stochastic, models commonly used in resource management and population viability analysis must provide probabilistic descriptions of the possible outcomes. Most models continue to model environmental fluctuations as a "white noise" process, where successive fluctuation values are statistically independent, despite the fact that much recent work (1) has demonstrated hat environmental noise tends to be temporally autocorrelated, or "reddened." While interest in understanding the impact of a colored noise environment as compared to white noise environment on the extinction risk of a population has grown rapidly in recent years (2,3), conclusions have differed widely and appear to depend on the particular form of the model being investigated.

Recent investigations have relied on simple models built around deterministic population models where a single parameter is allowed to vary stochastically in the simulation (3,4). I propose to develop an individual based, spatially explicit simulation model in which to explore the impact of colored environmental noise on extinction risk. Using a spatially explicit individual model it is possible to explore how environmental fluctuations enter and propagate through a population, and could be more directly adapted for comparisons to particular data–sets. The combinatorial complexity and the ability to run the same simulation in different regions of the parameter space in parallel on many different computer nodes makes the INCITE supercomputers (i.e. Blue Gene/P) ideal for this research.

1) Vasseur D & Yodzis P (2004) Ecology, 85:4, 1146 52.

2) Green J et al, (2005) Biosci 55:6, 501–10.

3) Ripa J & Lundberg P, (1996). Proc. Biol. Sci., 263:1377, 1751–53.

4) Petchey O et al. (1997) Proc. R. Soc. Lond. B, 264, 1841–47.

4. List of publications

1) Wray, J., Bahcall, N., Bode, P., Boettiger, C., Hopkins, P. (2006) "The Shape, Multiplicity, and Evolution of Superclusters in Î›CDM Cosmology." Astrophysical Journal 652, 907.
2) Boettiger, C., Dushoff, J., Weitz, J. "Variation in the phenotypic dynamics of evolving populations," Proc. Roy. Soc. Lon. B, (in review).
3) Boettiger, C. "Clonal Inteference Models in Population Genetics," Princeton University, Junior paper, 2006.

4) Boettiger, C. "Adaptive Dynamics: Branching Phenomena and the Canonical Equation," Princeton University, Junior Paper, 2006.
5) Boettiger, C. "Ensemble behavior from individual dynamics in forest populations," Thesis, Princeton University, 2007.

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Completed Courses

List appropriate courses from science or engineering, mathematics, and computer science that you have completed. Please note that numerical analysis courses should be listed under "mathematics". Provide course number and title, credit hours, grade earned, and whether the course is undergraduate (U), graduate (G), or offered for either undergraduate or graduate credit (B).

Course number	Course Title	Credit hours	Term and Year	Grade	Academic Level
Science/Engineering					
ELE 573	Cellular and Biochemical Computing Systems	3S	Fall 2006	A	G
GEO 523	Geomicrobiology	3S	Spring 2005	A	G
MOL 342	Genetics	3S	Fall 2006	A–	U
MOL 515	Method and Logic in Quantitative Biology	3S	Spring 2006	A–	G
PHY 301	Thermal Physics	3S	Fall 2005	A	U
PHY 562	Biophysics	3S	Spring 2006	A	G
Mathematics and Statistics					
MAT 317	Complex Analysis	3S	Spring 2005	B	U
MAT 350	Introduction to Differential Equations	3S	Fall 2005	A–	U
MAT 351	Mathematical Modelling	3S	Fall 2006	B	B

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Program of Study

Listed are the courses in science and engineering, applied mathematics, and computer science that you agreed to take on your proposed Program of Study.

University: University of California, Davis

Course number	Course Title	Credit hours	Term and Year	Grade	Academic Level
Science/Engineering					
ECL 232	Theoretical Ecology	3Q	Winter 2008		G
PBG 200A	Principles of Population Biology	5Q	Fall 2007	A	G
PBG 200B	Principles of Population Biology	6Q	Winter 2008		G
PBG 200C	Principles of Population Biology	6Q	Spring 2008		G
PBG 231	Mathematical Methods in Population Biology	3Q	Fall 2007	A+	G
Mathematics and Statistics					
MAT 204	Applied Asymptotic Analysis	4Q	Fall 2009		G
MAT 236A	Stochastic Dynamics and Applications	4Q	Fall 2008		G
MAT 236B	Stochastic Dynamics and Applications	4Q	Winter 2009		G
Computer Science					
ECS 222A	Design and Analysis of Algorithms	4Q	Fall 2008		G
ECS 223	Parallel Algorithms	4Q	Winter 2009		G
ECS 231	Large–Scale Scientific Computation	4Q	Winter 2009		G

I have read this program of study and affirm that, in my opinion, it satisfies the fellowship program requirements. This POS has been approved by my advisor, **Alan Hastings**, and I understand that, if offered a fellowship, my advisor and I are required to sign this page and send it to the Krell Institute.

Student's signature ____________________________ Date _______________

Graduate Advisor: **Alan Hastings**

Graduate Advisor's Institute: **University of California, Davis**

Graduate Advisor signature ____________________________ Date _______________

Krell Institute (Office use only) __________________________________

DOE Computational Science Graduate Fellowship Program
Krell Institute

Attn: DOE CSGF Coordinator
1609 Golden Aspen Drive, Suite 101
Ames, IA 50010
Phone: 515–956–3696
Fax: 515–956–3699
csgf@krellinst.org

Name: Carl Boettiger

Course Description

ECL 232: Theoretical Ecology

Examination of major conceptual and methodological issues in theoretical ecology. Model formulation and development will be emphasized.

PBG 200A: Principles of Population Biology

Principles of single–species ecology and evolution. Topics include ecology of individuals, population growth models, structured populations, life history strategies, stochastic populations, basic population genetics theory, deleterious alleles in natural populations, and molecular population genetics.

PBG 200B: Principles of Population Biology

Principles of multi–species communities. Topics include competition, mutualism, metapopulations, food webs and trophic cascades, interactions between simple ecological communities, island biogeography, succession, and large–scale patterns.

PBG 200C: Principles of Population Biology

Principles of microevolution and macroevolution. Topics include evolutionary quantitative genetics, analysis of hybrid zones, speciation, the fossil record, biogeography, and phylogeny reconstruction.

PBG 231: Mathematical Methods in Population Biology

Mathematical methods used in population biology. Linear and nonlinear difference equation and differential equation models are studied, using stability analysis and qualitative methods. Partial differential equation models are introduced. Applications to population biology models are stressed.

MAT 204: Applied Asymptotic Analysis

Scaling and non–dimensionalization. Asymptotic expansions. Regular and singular perturbation methods. Applications to algebraic and ordinary and partial differential equations in the natural sciences and engineering.

MAT 236A: Stochastic Dynamics and Applications

Stochastic processes, Brownian motion, Stochastic integration, martingales, stochastic differential equations. Diffusions, connections with partial differential equations, mathematical finance.

MAT 236B: Stochastic Dynamics and Applications

Stochastic processes, Brownian motion, Stochastic integration, martingales, stochastic differential equations. Diffusions, connections with partial differential equations, mathematical finance.

ECS 222A: Design and Analysis of Algorithms

Techniques for designing efficient algorithms, analyzing their complexity and applying these algorithms to a broad range of applications. Methods for recognizing and dealing with difficult problems.

ECS 223: Parallel Algorithms

Models of parallel computer systems including PRAMs, loosely coupled systems and interconnection networks. Parallel algorithms for classical problems and general techniques for their design and analysis. Proving lower bounds on parallel computation in several settings.

ECS 231: Large–Scale Scientific Computation

Algorithms and techniques for large–scale scientific computation, including basics for high performance computing, iterative methods, discrete approximation, fast Fourier transform, Poisson solvers, particle methods, spectral graph partition and its applications.

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Additional comments

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Demographics (Optional)

Applicant data is important in assessing the effectiveness of our efforts to solicit applications from a diverse population. Your completion and submission of this form will assist us in this regard. Providing the information on this form is voluntary; omission of information will not affect any decision about your application. We appreciate your cooperation.

Race: **Caucasian**

Gender: **Male**

Physical/mental disability : **No**

Fellowship Survey (Optional)

The information that you provide will allow us to target our advertising more effectively. This information is confidential and is not used in review of the fellowship application.

1. How did you find out about the program?

- ☐ DOE CSGF Poster
- ☐ DEIXIS, DOE CSGF annual publication
- ☐ Advertising in journal
  Name of journal:
- Word of mouth from
  - ☑ faculty
  - ☑ student
  - ☐ administrator
- ☐ Laboratory Staff
- ☐ Institutional Announcement
- ☐ Conference or Meeting
  Name:
- ☐ World Wide Web
  List URL:
- ☐ Other
  Explain:

2. Have you applied for other fellowship programs?

- ☐ University–Sponsored
  Names of fellowships:
- ☐ Other (NSF, DOD, Hertz, ATetc.)
  Names of fellowships: